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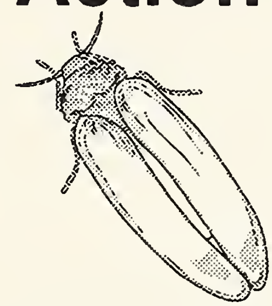
Silverleaf Whitefly

(Formerly Sweetpotato Whitefly, Strain B)

1994 Supplement to the Five-Year National Research and Action Plan



Second Annual Review
Held in Orlando, Florida
January 24–27, 1994

In cooperation with—
USDA/Cooperative State Research Service and the
State Agricultural Experiment Stations
USDA/Animal and Plant Health Inspection Service
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While supplies last, single copies of this publication may be obtained at no cost from Robert M. Faust, U.S. Department of Agriculture, Agricultural Research Service, BARC-West, Bldg. 005, Rm. 338, Beltsville, MD 20705.

Copies of this publication may be purchased from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161.

Editors' Comments

The first annual progress review of the multiagency sweetpotato whitefly research and action plan was conducted at Tempe, AZ, 18-21 January 1993. Over 200 individuals attended and participated in the meeting and 117 abstracts of research progress were submitted and published in: USDA 1993, Sweetpotato Whitefly: 1993 Supplement to the Five-Year National Research and Action Plan. USDA-ARS, ARS-112, 178 pp., U.S. Govt. Printing Office, Washington, DC. The enclosed compilation of 146 abstracts from the second annual progress review represents the continuing efforts of federal and state agencies and agricultural industries to develop effective management of sweetpotato whitefly populations. The editors appreciate the contributions of all attendees and participants. The title of this manuscript recognizes the redescription of the sweetpotato whitefly strain as a new species[1]. The new suggested common name, silverleaf whitefly, and scientific name, *Bemisia argentifolii* N sp., are synonymous with whitefly, sweetpotato whitefly, *B. tabaci* (Gennadius), and sweetpotato whitefly Strain B within this publication.

The research reports herein are in the form of summaries of current state-of-the-art studies designed to provide a knowledge base for development of economic, environmentally compatible and socially acceptable sweetpotato whitefly management systems. The abstract contents remain the sole responsibility of the authors. Other sections of this document are the combined effort of the meeting participants and other interested contributors. Minor editing was done only to conform to camera-ready format requirements.

Editors: T.J. Henneberry, N.C. Toscano, R.M. Faust, and J.R. Coppedge

[1] Bellows, T.S., Jr., T.M. Perring, R.J. Gill, and D.H. Headrick. 1994. Description of a species of *Bemisia* (Homoptera: Aleyrodidae). Ann. Entomol. Soc. Am. 87:195-206.

Progress Review Organizational Team

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Dennis D. Kopp, USDA Extension

Annual Review Program Chairmen

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Local and State Coordinators

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Acknowledgments

The National Coordinators, Program Chairmen, and Technical Committees sincerely appreciate the contributions of all the participants and others who have helped in organizing the meeting. We especially thank Deanna Guy, Lynn Jech and Marilyn Reega for their help in assuring the success of the meeting.

Contents

Foreword

Following the late 1980's, epidemic outbreaks of the sweetpotato whitefly in California, Arizona, Texas and Florida, representatives of USDA agencies, State Experiment Stations and commodity-involved industries collaborated to develop a comprehensive 5-year National Research and Action Plan to develop methodology for control and management of the sweetpotato whitefly. Multiagency, commodity, industry and agricultural community representatives participated in meetings at Atlanta, GA, Reno, NV and Houston, TX in late 1991 and early 1992, resulting in an extensive conference report, and a developed research and action plan that established the six highest priority research areas as (1) Ecology, Population Dynamics and Dispersal, (2) Fundamental Research-Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus-Vector Interactions, (3) Chemical Control, Biorationals, and Pesticide Application Technology, (4) Biological Control, (5) Crop Management Systems and Host Plant Resistance, and (6) Integrated Techniques, Approaches, and Philosophies.

Additionally, in 1992, a USDA Sweetpotato Whitefly Research, Education and Action Coordinating Group (two members from ARS, two members from APHIS, two members representing CSRS/SAES, and one member from ES) was formed to unify USDA interagency activities. The USDA Interagency Group and partner State Agricultural Experiment Stations provide coordination for USDA research and education needs, and implementation of resources to provide solutions leading to control and management of this serious pest.

The National 5-Year Research and Action Plan requires an annual review to (1) establish a forum for exchange of research information and ideas, (2) plan cooperative work, and (3) evaluate research progress in relation to goals, objectives and priorities. The review process also identifies areas where research is lacking and provides the framework for recommendations for (1) reassigning or deleting existing priorities, (2) adding additional priorities, (3) making other adjustments in the plan that may be necessary to accommodate the research effort within the constraints of available resources, and (4) planning the most efficient and productive use of additional funds that may become available to the research and action communities.

The results of the first annual progress review in Tempe, AZ in January of 1993, showed substantial progress in all of the national plan's priority areas. Extensive national effort was expended to provide immediate and short-term relief from SPW losses in the agricultural community. Basic and fundamental information on natural enemies, biology, virus-vector relationships, host plant interactions and population dynamics is being developed to provide a firm base for the development of efficient long-term and acceptable strategies to manage SPW populations.

A coordinated national testing program to evaluate chemical and biorational approaches on key cultivated crops identified several materials alone or in combination that provided some relief for farmers during the 1993 growing season using conventional approaches. Excellent progress was made in developing insecticide resistance management strategies and chemical control rotational systems to maximize longevity of materials used in management programs.

Biological control initiatives with indigenous natural enemies, potential microbial materials, imported exotic biological materials progressed favorably.

Finally, the broad scope of research investigating behavior, biochemistry, physiology, morphology and systematics is providing significant information that is contributing to development of long-term economic and socially acceptable integrated pest management strategies with an ecological base.

Development of the 5-Year Plan and the annual progress reviews in 1993 and 1994 have been the result of the combined efforts of all participating Federal and State agencies and the agricultural industries.

The members of the USDA Whitefly Research, Education and Action Coordinating Group are deeply appreciative for the contributions of all of the individuals who have made the progress reviews and 5-Year Plan a successful endeavor. Special appreciation this year is accorded to Drs. T. J. Henneberry and N. C. Toscano, Annual Review Program Co-Chairs and their staffs, to the SPW Technical Committee, to the National and local Coordinators, and to the Program Chairs for their substantial efforts in this process. Particular appreciation is accorded to Dr. R. E. Mayer, P. A. Stansly and Harold Browning and their staffs for local arrangements.

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Executive Summary

The 5-Year National Sweetpotato Whitefly Research and Action Plan has been a focal point for a Federal, State, and agricultural industry intensive effort to provide research information leading to control and management of this serious insect pest in the agricultural community.

As a worldwide pest it has been known as the cotton, "poinsettia," cassava and tobacco whitefly. In the United States, the SPW was recorded in Florida from sweetpotato plants as early as 1894, but economic populations were not reported until 1986. The SPW has become of increasing importance since the early 80's in cotton production systems in Arizona and California, the late 80's in Texas, as well as in cultivated vegetable crops in the three states. The SPW has also become an important pest in the northeast U.S. where it is found infesting greenhouse grown ornamentals in several states. With these outbreaks and more recent problems in numerous crops in Texas, Arizona, and California, it has become apparent that the whiteflies now causing these problems exhibited biological differences from the original southwestern U.S. population. The epidemic outbreaks of the SPW in Arizona and California beginning in the early 1980's, as well as those in Texas in 1988 and in Florida in 1987 remain unexplained; although it has been suggested that the recent outbreaks, different host preferences, and other biological differences are consistent with the introduction of an exotic SPW population, possibly even a closely related but different species.

The taxonomic relationships and the synonymy of the species have been reviewed on several occasions. Taxonomic confusion has arisen because of the variation in several morphological characters as well as the SOW varied host plant associations and the effect of host plants on morphological characteristics. Further, SPW race and/or biotype designations have also often been recorded in past literature in relation to host affinities and virus transmission vector interactions. The possibility of biotype occurrence has received new interest with the increasing importance of SPW in crop production on a worldwide basis. The detection of differences in electrophoretic isozyme patterns, biology and extended host range have provided evidence for the existence of different SPW biotypes as compared to SPW previously encountered in the desert Southwestern United States crop production areas. The biotype has been referred to in the literature as the SPW strain B. Based on available information and expanded studies using polymerase chain reaction-based DNA differentiation tests, allozymic frequency analysis, crossing experiments, and mating behavior observations, suggested that the SPW strain B is a distinct species, and named the "silverleaf whitefly". The origin of the new species remains unknown -- this must be determined as soon as possible to develop information on biotic and abiotic population regulating factors in its natural environment.

The annual progress reviews show substantial research progress in methods to provide immediate and long-term relief from losses as a result of the SPW and to provide a firm base for the development of efficient long-term and acceptable strategies to manage SPW populations.

Several chemical and biorational materials alone or in combination have been identified to provide control using conventional approaches. Further, excellent progress has been made in developing insecticide resistance management and chemical control rotational systems to assure maximum longevity of existing materials. Biological control initiatives also appear promising and research investigating behavior, biochemistry, physiology, morphology and systematics is providing significant information that is contributing to development of long-term economic and socially acceptable integrated pest management strategies with an ecological base.

The National 5-Year Research and Action Plan continues to provide direction and research implementation for a coordinated, cooperative effort by the agricultural community to provide short and long-term sweetpotato whitefly management systems. The review process is a forum for research exchange and formulation of ideas, stimulates cooperative work and tracks research progress in relation to goals, objectives and priorities.

Annual Review Objectives

Annual research progress reviews are an integral part of the 5-year national sweetpotato whitefly research and action plan. The plan defines six high priority research areas and research approaches designed to achieve the goals and objectives of the plan within a 5-year timeframe. The plan remains open-ended and provides for modification, termination, or reduced research effort in areas of poor progress and estimated potential for successfully providing useful information for sweetpotato whitefly control and management. It also provides for identification of new areas of research not covered in the plan and/or redirection of existing or establishment of new research priorities. The objectives of the annual review process will be to provide (1) presentations of research progress in each research priority area of the plan, (2) provisions for intense scrutiny of research programs in relation to goals and objectives of the research approaches, (3) opportunity to discuss the significance of the research progress in relation to impact on development of technology to solve the sweetpotato whitefly problem and finally, (4) for making recommendations regarding appropriateness of existing priorities and need for adjustments in the plan.

Current Status of Research on the Sweetpotato Whitefly 5-Year National Research and Action Plan

The 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly (SPW) was formulated in late 1991-early 1992 following epidemic outbreaks of the SPW in California, Arizona, Texas and Florida beginning in the late 1980's. Infestations in 1992 and 1993 on cotton and numerous ornamental crops in the San Joaquin Valley, CA, as well as local infestations in Georgia, South Carolina, and other states suggested that the full extent of the problem may not yet be realized.

Federal and State research and action agencies and representatives of the agricultural commodities industries recognized the need for a national plan to optimize research effort and obtain maximum return within existing resources. The developed Research and Action Plan provides direction and research implementation for a coordinated, cooperative effort by the agricultural community to provide short and long-term solutions leading to the development of SPW management systems. Crop loss estimates for 1991 and 1992 range from $200 - $500 million dollars. In 1993, the agricultural community was better equipped to deal with the SPW as more information has been developed through Federal and state research agencies. Of particular note has been information developed on crop sequencing and SPW interactions, development of several effective insecticides and insecticide combinations, resistance management methodology, improved application technology and basic biological and ecological knowledge of the SPW. Much effort has been directed to resolving the nomenclature and classical taxonomic relationships of SPW which have been confused for many years. The SPW has been referred to in the literature as the cassava whitefly, tobacco whitefly, poinsettia whitefly, and cotton whitefly, as well as *B. tabaci*. The taxonomic relationships and the synonymy of the species have been reviewed on several occasions. Also, SPW race and/or biotype designations have also often been recorded in past literature in relation to host affinities and virus transmission vector interactions. The possibility of biotype occurrence has received new interest with the increasing importance of SPW in crop production on a worldwide basis. The detection of differences in electrophoretic isozyme patterns, biology and extended host range have provided evidence for the existence of different SPW biotypes as compared to SPW previously encountered in the desert Southwestern United States crop production areas. The biotype has been referred to in the literature as the SPW strain B. Based on available information and expanded studies using polymerase chain reaction-based DNA differentiation tests, allozymic frequency analysis, crossing experiments, and mating behavior observations, it has been suggested that the SPW strain B is a distinct species, and is referred to as the "silverleaf whitefly". This development may necessitate reinvestigation of key biological and ecological relationships.

High SPW populations occurred in California and Arizona in 1993, with increasing acreages of infestation found in the San Joaquin Valley. Even though insecticides were used extensively, sticky cotton is apparent and reports of cotton leaf crumple are cause for concern. The increasing number of occurrences of gemini-type viruses in various vegetable crops adds a further dimension to the seriousness of the SPW problem. In Texas, early season populations on cotton were low, but expected to increase dramatically and become a serious problem for winter vegetable production. Florida experienced higher SPW populations in 1993 compared to 1992. Also, cotton mosaic disease of leaves caused by a SPW-vectored virus appeared for the first time in the U.S. and high incidences of tomato mottle geminivirus were reported. Georgia experienced light SPW infestations in cotton, peanuts and vegetables, but remained an economic level pest in greenhouse ornamentals and in outdoor nurseries. Control costs for 1993 were estimated to exceed the $18.9 million 1992 costs.

The annual review process for the 5-Year National Plan functions to analyze and evaluate progress made in reaching the Plan's defined goals, and reexamines directions of research and priority focus, with the purpose of re-establishing initial priorities or making appropriate changes or new priorities based on current

knowledge. It also falls within the purview of the review team to identify deficiencies in the research that can be addressed with redirections of current resources or supplemented with new resources.

The first annual progress review was held January 18-21, 1993 at Tempe, AZ. The 117 submitted and published abstracts show that contributions reflecting research activity and research progress were made by APHIS and ARS and seven State organizations (Table 1).

Table 1. Numbers of Research Reports[a] at the 1993 Sweetpotato Whitefly Annual Review of Research and Action Progress on the 5-Year National Plan.

	Research Priorities[b]						
Agency/State	A	B	C	D	E	F	Total
APHIS	0	1	0	1	0	1	3
ARS	7	11	19	13	7	0	57
AZ	2	3	4	1	0	1	11
CA	3	3	4	2	3	0	15
FL	2	3	2	2	2	1	12
GA	0	0	4	0	2	0	6
NY	1	0	1	1	0	0	2
OH	0	0	1	1	0	0	2
TX	1	1	2	0	2	2	8
TOTAL	16	22	37	21	16	5	117

[a] From USDA 1993. Sweetpotato Whitefly: 1993 Supplement to the Five-Year National Research and Action Plan, USDA-ARS, 112, 178 pp.
[b] A = Ecology, population dynamics and dispersal; B = Fundamental research, behavior, biochemistry, biotypes, morphology, physiology, systematics, virus diseases and vector interactions; C = chemical control, biorationals and pesticide application technology; D = Biocontrol; E = Crop management systems and host plant resistance; F = Integrated techniques, approaches and philosophies.

The highest number of abstracts (37) were in the area of chemical control, biorational insecticides and insecticide resistance management. Thereafter in decreasing order were fundamental biology, biological control, ecology, population dynamics and dispersal, crop management and host plant resistance and integrated systems with 22, 21, 16, 16, and 5 abstracts, respectively. The distribution of research effort as reflected by the numbers of abstracts in the respective research areas appears to show a balanced and well considered research effort that meets the needs of the agricultural community. Extensive national effort was expended within the first program year to provide immediate and short-term relief from losses as a result of the SPW. But also, considerable effort was devoted to developing basic and fundamental information on natural enemies, biology, virus-vector relationships, host plant interactions and population dynamics that will provide a firm base for the development of efficient long-term and acceptable strategies to manage SPW populations. Additionally, within the perspective of available resources and developed and developing technology, integrated systems with input such as risk assessment, modeling and communication-information systems, although progressing slowly, are provided for in the plan.

Extension and Education activities in the Imperial and San Joaquin Valleys of California, Arizona, Texas, and Florida have resulted in dissemination of updated information to the grower community. In the Imperial Valley, CA, a highly successful resistance management program has been developed and

progressed to the implementation stage with a weekly newsletter to growers with information on resistance ratios and chemical control efficacy with chemicals being used. An insecticide resistance management working group has been established to advance the technology transfer on a national basis. The combined efforts through interagency cooperation has further resulted in development of state sweetpotato whitefly management committees providing information at monthly, or more frequent, meetings, computer bulletin boards and development of slide and video sets with current status of water management, fertilization, crop management and crop sequencing, chemical control methodology and other information on a timely and useful basis during the growing seasons.

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Reports of Research Progress

A. Ecology, Population Dynamics, and Dispersal

Chairs: Steve E. Naranjo and Marshall Johnson

INVESTIGATOR'S NAME(S): Jackie Blackmer and David N. Byrne

AFFILIATION & LOCATION: University of Arizona, Tucson, AZ

RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal.

DATES COVERED BY REPORT: 1992-1993

HOST-PLANT EFFECTS ON LIFE-HISTORY TRAITS AND FLIGHT BEHAVIOR OF *BEMISIA TABACI*

Recently, we completed a study with *Cucumis melo* to determine whether changes in amino-acid levels affect the life-history traits and flight activity of *B. tabaci*. For 12 weeks, melon plants were infested with 20 pairs of whiteflies, which were allowed to oviposit for 24 h. Eggs were counted and plants returned to the greenhouse until the new generation began to emerge. Emergence rates, developmental time, adult weight and flight propensity were determined for this new generation. After the whiteflies emerged, the same leaf was removed for phloem collection. Two peaks in amino acids were observed: an initial large peak and a smaller peak associated with senescence. In young to mature plants, 23 amino acids were identified, 11 of those were found in almost all of our samples. In the last six weeks of the growing season, fewer amino acids were identified and their concentrations were reduced (16,483 pmol vs. 4063 pmol/50 μl of phloem sap). Glutamic acid, glycine, alanine, citrulline, isoleucine, leucine and histidine were found in nearly all of our samples, albeit in lower concentrations as the plants aged. Tyrosine and phenylalanine were found in almost all samples during the first six weeks, but were found only rarely thereafter. In general, as amino acid concentration increased, so did the number of eggs laid ($r^2 = 0.17$, $P < 0.004$, df = 1,45). As the plants senesced the number of eggs laid per female increased disproportionately, relative to the increase in total amino acids. Perhaps, one or a combination of a few amino acids will prove to be more indicative of egg-laying preference. Because emergence rates, developmental time and weights were determined approximately 20 days after oviposition data, a 2-4 wk lag in amino acid concentrations versus each of these parameters provided better coefficients of determination. As developmental time increased, emergence rate decreased, suggesting a possible connection to amino acid concentrations ($r^2 = 0.34$, $P < 0.07$, df = 1,8 and $r^2 = 0.49$, $P < 0.05$, df = 1,6, respectively). Female and male weight were similarly related to amino acid concentrations (r^2 0.68, $P < 0.006$, df = 1,7 and $r^2 = 0.96$, $P < 0.001$, df = 1,7, respectively).

We examined the flight propensity of this new generation of whiteflies and found that they were reluctant to fly. Upon examining egg load, we found that they were retaining a high number of mature eggs. A preliminary study examining why whiteflies retained their eggs, suggests an interaction between the number of whiteflies 'competing' for oviposition sites and leaf age. When single pairs of whiteflies were placed on melon, in clip cages, no relationship was found between number of eggs oviposited per female and leaf age or between number of eggs retained and leaf age. However, when 10 pairs of whiteflies were placed in clip cages, fewer eggs were laid (per female) on older leaves and more eggs were retained in females placed on older leaves. Previously, we demonstrated that flight duration was not inhibited by egg proteins; however, we did not know if the vitellogenin was in the fat bodies, hemolymph or eggs. To address this concern, we flew female whiteflies for varying lengths of time (up to 2.5 h), collected them after their flight and cleared they in xylene so that egg load could be determined. We found that the presence of more than four mature eggs did inhibit long-duration flights. Fewer than four mature eggs, however, did not seem to inhibit the flight activity of *B. tabaci*. In a final study, designed to address the question of how host quality affects flight duration, we used three categories of *C. melo*: young, mature and senescing. In all plant categories, the flight-duration distributions were highly skewed and long-duration flights were observed; however, the frequency of long-duration flights increased when the melon plants began to senesce ($X^2 = 30.24$, P 0.001).

INVESTIGATOR'S NAME(S): David N. Byrne and Jackie Blackmer

AFFILIATION & LOCATION: University of Arizona, Tucson, AZ

RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal.

DATES COVERED BY REPORT: 1992-1993

BEHAVIORAL, MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS ASSOCIATED WITH MIGRATORY *BEMISIA TABACI*

We found that the number of whiteflies taking off and exhibiting a positive response to sky light in the greenhouse was greatest from 0830 to 1000 h. During peak flight activity less than 5% of the population engaged in phototactic orientation and this response was short-lived (approximately 1 day). Temperature was the best predictor for the phototactic response, accounting for 75% of the variability in whitefly ascent. Addition of solar radiance, relative humidity and time of day explained only 6% more of the variation in ascent ($r^2 = 0.81$, $P < 0.0005$). Males were more prevalent on plants (1:0.76; $x^2 = 10.94$, $P < 0.05$), whereas females were much more prevalent (1:3.02; $x^2 = 97.77$, $P < 0.005$) among whiteflies responding to sky light. A higher percentage of the females displaying a phototactic response contained eggs when compared to females remaining on their host plant (87 vs. 65%, $P < 0.05$). Whiteflies exhibiting a phototactic response in the greenhouse were more likely to exhibit long-duration, phototactic flights in a vertical flight chamber, compared to individuals that remained on the host plant (80.7 ± 6.7 vs. 36.0 ± 5.8% phototactic response; 7.0 ± 3.2 vs. 0.7 ± 0.2 min flights). Consequently, we have designated these individuals as being "pre-migratory whiteflies."

Variation in response to vegetative cues during phototactically-oriented flight was examined in the vertical flight chamber, which was equipped with a 550 ± 2 nm narrow-band interference filter (simulating the host plant). When whiteflies were presented with this visual cue for 3 s during each minute of flight, 76% landed on the target within three presentations. Another 18% of the whiteflies displayed an intermittent attraction to the host cue, and 6% displayed a response that historically has been considered to be indicative of migration. These three categories of response were observed in both sexes, in all flight-capable individuals from 1-5 d old and in two groups of whiteflies that were exhibiting distinct behaviors prior to our tests (i.e., one group was settled on their host plant, and the other group was "pre-migratory".

To determine whether morphological differences were associated with flight capacity, fore- and hindwings were photographed and five characters were measured using a digitizing tablet. We found an inverse relationship between wing dimensions and flight duration for males; however, we found no relationship between flight duration and wing characteristics for females.

To determine whether *B. tabaci* exhibited the oogenesis-flight syndrome, females were flown for varying lengths of time (up to 2.5 h), weighed, placed in microcentrifuge tubes and stored at -80°C. These samples were analyzed for levels of vitellogenin and vitellin by using an egg-specific monoclonal antibody (MAb) in conjunction with an enzyme-linked immunosorbent assay. We found small but significant increases in egg-protein levels with longer flights and increasing weights. We also compared the levels of egg proteins in settled and pre-migratory whiteflies (with or without an extended period of flight) and found that pre-migratory whiteflies always had higher levels of egg proteins in comparison to settled whiteflies. This technique, however, does not allow for separation of egg proteins in the fat body,hemolymph or in the form of mature eggs. The location, rather than the quantity of these egg proteins may be more important in affecting the behavior manifested.

INVESTIGATOR'S NAME(S): Heather Costa, Diane E. Ullman, Marshall W. Johnson, Bruce E. Tabashnik

AFFILIATION & LOCATION: Department of Entomology, University of Hawaii, Honolulu, HI

RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal.

DATES COVERED BY REPORT: 1992-1993

ASSOCIATION BETWEEN *BEMISIA TABACI* DENSITY AND REDUCED GROWTH, YELLOWING AND STEM BLANCHING OF LETTUCE AND KAI CHOY

Colonization by high densities of sweetpotato whitefly, *Bemisia tabaci*, B Biotype, reduced growth of lettuce (*Lactuca sativa*) and kai choy (*Brassica campestris*). Weight loss increased as immature density increased, indicating that the greater the number of immatures feeding, the more severe the damage. In kai choy, all plants exposed to 10 or more adult whiteflies and their nymphal offspring for three weeks developed symptoms of stem blanching and leaf curling on new growth, while plants without whiteflies remained symptom free. Exposure to 200 adult whiteflies for 48 hr, with nymphs removed, did not induce weight loss or symptom development. Removal of whiteflies from symptomatic plants using insecticides resulted in nonsymptomatic new growth. The increase in symptoms with increasing numbers of whiteflies and the recovery of new growth following whitefly removal support the hypothesis that these syndromes are the result of toxicogenic response rather than a pathogenic relationship.

Publications:

Costa, H. S., D. E. Ullman, M. W. Johnson and B. E. Tabashnik. 1993. Association between *Bemisia tabaci* density and reduced growth, yellowing, and stem blanching of lettuce and kai choy. Plant Distase. 77: 969-972.

Costa, H. S., D. E. Ullman, M. W. Johnson and B. E. Tabashnik. 1993. Squash silverleaf symptoms induced by immature, but not adult, *Bemisia tabaci*. Phytopathology. 83: 763-766.

INVESTIGATOR'S NAME(S): Peter Ellsworth and Donna Meade

AFFILIATION & LOCATION: University of Arizona, Maricopa Agricultural Center, Maricopa, AZ

RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY REPORT: 1993

ACTION THRESHOLDS FOR WHITEFLIES IN ARIZONA

Three field tests were set-up for evaluation of action threshold levels for SPWF control with 2 different chemical combinations. The thresholds used to initiate treatments were ca. 1, 10, and 25 adult SPWFs per leaf designated as, "early", "moderate", or "late". Immatures were present during these treatment initiation points at the rate of ca. 5 nymphs and ca. 10 eggs per sq.in. in the "early" plots, 15.3 nymphs and 39.1 eggs per sq.in. in the "moderate" plots, and 52.1 nymphs and 299.3 eggs per sq.in. in the "late" plots. The insecticides used included a pyrethroid combination [Danitol® (.1 lb ai/A) + Orthene® (.5)] and a non-pyrethroid combination [endosulfan (.75) + Ovasyn® (.25)]. Applications were by ground, broadcast, over-the-top, at 20 GPA. Populations were monitored as adults (leaf turns & net sweeps) and nymphs and eggs (leaf counts). Once applications were triggered, they continued ca. weekly. The early threshold required 7 applications, starting 10 July, and produced yields (4038.8 lbs seed cotton/A), which were 2 or 3 times larger than the untreated check (1589.3 lbs seed cotton/A). Lint or leaf stickiness was not apparent; however, 2 or 3 sprays were required before any significant differences in SPWF populations could be found. SPWF numbers were lowered significantly in both insecticide regimens, with somewhat lower numbers present in the pyrethroid treated plots. The late threshold was sprayed only twice, starting 12 August, and yielded no more cotton (1719.2 lbs seed cotton/A) than the untreated check (1395.0 lbs seed cotton/A). Lint and leaf surfaces were covered in stickiness and sooty mold. SPWF populations were excessive and led to premature cut-out and poor fruit retention. The moderate threshold (10 adults per leaf) received 5 applications, starting 22 July, and produced high yielding and high quality cotton (3462.2 lbs seed cotton/A). Some stickiness and sooty mold growth was observable only on the lowest leaves. This was a result of limited honeydew production prior to the threshold and well before any boll opening. Lygus populations were extremely high and caused large differences in yields which favored the pyrethroid combination slightly and the earliest threshold significantly. Given commercial farm control realities (e.g., delays in sampling or application, differences in coverage or application, variable efficacy), the ideal threshold for initiation of treatments is likely between 1-10 adults/leaf.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal.

DATES COVERED BY REPORT: 1 May 1993 - 1 December 1993.

INTRAPLANT DISTRIBUTION OF SILVERLEAF WHITEFLY ON ACALA COTTON

The with-in plant distribution of silverleaf whitefly (sweetpotato whitefly - strain B [SWF]) was studied on acala cotton in Kern county (San Joaquin Valley, California). All SWF (all lifestages) were counted from the main stem node leaves from 15 cotton plants in September, 1993. This field had a severe infestation of SWF that started in July. The plants generally had 14 main stem node leaves with leaf 1 being designated at the terminal and leaf 14 nearest the plant base. The highest population of eggs was found on leaves 2-6 and ranged from 12.2 to 15.5% of the total egg population. Small nymphs were most common on leaves 3-5 (16.5 to 22.9% of the total), red-eye nymphs were most common on leaves 5-8 (15.1 to 19.8% of the total), and spent pupal cases were most common on leaves 6-8 (14.2 to 18.4% of the total). The leaves with the highest SWF populations also generally had the lowest coefficient of variation values. These data on within-plant distribution of SWF on cotton agree closely with data of Naranjo and Flint in Arizona. Cotton plants averaged 2033 SWF eggs, 369 SWF small nymphs, 52 red-eye SWF nymphs, and 111 spent pupal cases per plant on the main stem node leaves. SWF eggs and small nymphs were present on every main stem node leaf, red-eye nymphs were present on all main stem node leaves except 1 and spent pupal cases were present on all main stem node leaves except 1 and 2.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal.

DATES COVERED BY REPORT: 1 May 1993 - 1 December 1993.

CONTRIBUTIONS OF CROP AND WEED HOSTS TO SILVERLEAF WHITEFLY POPULATIONS IN THE SAN JOAQUIN VALLEY

Populations of silverleaf whitefly (sweetpotato whitefly - Strain B [SWF]) were sampled on crop and weed hosts within twelve long-term sampling sites in Kern, Kings, Tulare, Fresno, and Merced counties in the San Joaquin Valley of California. Each site encompassed ~36 sq. mi. These sites were chosen because of their diversity of crops, the presence of crops from October to March (fall melons, broccoli, alfalfa, potatoes, field roses, etc.), significant areas of weeds, and the presence of SWF populations the previous year in the vicinity. Sampling in these areas began on 1 May 1993 and has continued to the present. Within each area, three sites of all potential SWF host plants, crops and weeds, were sampled every 2 weeks; all red-eye SWF nymphs were counted for 10 minutes during a visual examination of foliage.

SWF were first detected in moderate densities in mid-July. In Kern county (the southernmost location), SWF were found in a honeydew melon field on 2 June at low levels and the population increased to ~250 nymphs per 10-minute search. Within this same area, SWF were first found in cotton on 27 July and populations increased to ~325 per 10-minute search on 22 September. In summary, SWF have been found in 10 of our 12 sample sites. In the Kings county site, SWF were first noted in cotton on 11 August (241 per 10-minute search) and the population increased to 4,070 per 10-minute search on 21 September. SWF populations occurred on alfalfa in mid-September, as cotton and other crop hosts were no longer conducive for SWF infestation. Other crop hosts with SWF included sweet potato, carrot, potato, daikon radish, kale, collards, lettuce, watermelon, beans, tomato, cantaloupe, field roses, broccoli, squash, cabbage, pepper, eggplant, cauliflower, and okra. SWF density varied greatly on these host plants. Numerous weed hosts (> 50 species) for SWF were also identified. The highest populations on weeds were found on Johnsongrass, lanceleaf groundcherry, tree tobacco, tolguacha, cheeseweed, spotted spurge, and prickly lettuce

In terms of geographical distribution, SWF were found throughout the southern end of the San Joaquin Valley, generally at low-moderate densities, starting in August. This pest was first found in Merced county (near Los Banos) and in Yolo county (southern end of the Sacramento Valley) in late September. No SWF were found in 1993 farther northward into the Sacramento Valley, i.e., Sutter, Yuba, or Colusa counties. The greatest spread of SWF was in Tulare County where it overwintered in and around a greenhouse. From this location, spread was detected ~5 miles north and west, up to 15 miles south, and 10 miles east (possibility of secondary foci to south and east).

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY REPORT: 1993

SWEETPOTATO WHITEFLY POPULATIONS AND COTTON LINT YIELD

Studies were conducted at the University of Arizona's Maricopa Agricultural Station, Maricopa, AZ in 1993 to determine the relationship between sweetpotato whitefly (SPW), *Bemisia tabaci* (Gennadius), populations and cotton lint yields. Six replicated fields, in each case, of untreated cotton plots, cotton plots treated 3 (3, 7 and 13 August) times with insecticides during the season, and cotton plots treated with insecticides weekly on 21 and 27 July and 3, 10, 19, and 25 August were sampled at weekly intervals throughout the season (22 June to 13 September). SPW adults were estimated using the black pan method and eggs and nymphs were counted on leaf discs from leaf samples taken in each plot. Numbers of all SPW stages were low in all plots through 6 July. Numbers of adults increased dramatically to more than 8500/pan sample on 9 August in untreated plots, 5000/pan in plots sprayed 3 times with insecticides during the season on 2 August, and 1000/pan on 9 August in plots sprayed weekly. SPW egg and nymphs followed similar trends, but peak populations in control plots were reached 16 August and decreased dramatically thereafter in association with cotton plant defoliation caused by the heavy SPW infestation. Highest populations of eggs and nymphs in plots treated 3 times during the season occurred on leaf samples taken 2 and 9 August and on 2 August for plots sprayed weekly. Seasonal average numbers of adults were 3308 $\pm$ 424, 1010 $\pm$ 166, and 432 $\pm$ 51; eggs were 468 $\pm$ 62, 139 $\pm$ 23 and 37 $\pm$8; nymphs 157 $\pm$ 21, 45$\pm$ 7, and 14 $\pm$ 1/cm^2 of leaf disc from untreated plots, plots treated 3 times during the season and plots treated weekly, respectively. Egg and nymph populations were highly correlated (r = 0.95 and r = 0.96, respectively) to adult populations, and nymphal populations were highly correlated to egg populations (r = 0.99). Cotton lint yields in untreated plots, plots treated 3 times and plots treated weekly were 382, 1296, and 1204 pounds/acre, respectively. Lint yields were negatively correlated to seasonal average SPW adult (r = 0.82), nymph (r = 0.90), egg (r = 0.89), and mean total (adult, nymph and egg) (r = 0.84) populations.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY REPORT: January 1 - December 1, 1993

DEVELOPMENT OF *BIOCONTROL-WHITEFLY*: A WHITEFLY/PARASITOID/ PREDATOR POPULATION DYNAMICS MODEL

A computer model (BIOCONTROL-PARASITE) that simulates host and parasitoid population interactions and plant damage in the *Lygus*/alfalfa system is currently being converted to simulate whitefly/parasitoid/predator population dynamics and interactions in the cotton system. The model (BIOCONTROL-WHITEFLY) integrates the component processes of natality, development and mortality. Based on recent data from the literature, the model uses a multiple-cohort approach to simulate distributed, temperature-dependent development and to maintain age-structure in the whitefly population. Although preliminary at this time, one of the major components of the model will be it's ability to simulate the effect of natural enemy populations on whitefly dynamics. The model is structured in a highly flexible manner that allows the user to input specific biological attributes and within-season sampling information of both the whitefly and various species of parasitoids and predators through pull-down menus. The model will also incorporate a component for chemical control and will utilize a simple cotton plant model for estimating the impact of whitefly populations on yield. We envision that the model will be useful for studying the basic dynamics of the system and in evaluating various management scenarios. For example, the model could aid the selection and evaluation of candidate parasitoids and predators for augmentative release. The timing of augmentative releases for maximum efficacy against whitefly could also be evaluated through simulation. The model could also be used as a means of testing the applicability and realism of data collected from laboratory experiments of host/parasitoid and predator/prey interactions. The model will run on IBM compatible and will be available to interested users upon request.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY REPORT: October 1992 - October 1993

COOPERATIVE RESEARCH, IMPLEMENTATION, AND ASSESSMENT PROJECT FOR SWEETPOTATO WHITEFLY BIOLOGICAL CONTROL IN THE LOWER RIO GRANDE VALLEY OF TEXAS

A collaborative research project on intensive sampling of the sweetpotato whitefly is currently being undertaken by USDA-ARS in Weslaco, units of the USDA-APHIS in Brownsville, Harlingen and Mission, the Texas Agricultural Experiment Station in Weslaco and Rio Farms, Inc. of Monte Alto, Texas. The objective of the project is to collect data on crop production and on the dynamics of the whitefly and its natural enemies as they are influenced by environment, crop type and management practices in the Lower Rio Grande Valley of Texas. Nine cotton fields were chosen for monitoring. The fields are located amidst citrus and sorghum cropping areas. These fields are located within a 1-square mile area and will be monitored continuously throughout the year. A separate field of kenaf (*Hibiscus cannabinus*), was also monitored because this is one field crop in the Rio Grande Valley which is not being sprayed with chemical insecticides.

Twenty-five yellow cards were placed randomly around the fields from July, 1993. The cards were replaced weekly and whiteflies were counted on a 3" x 3" area of each card. Whitefly counts in the cotton fields peaked to approximately 4000 adults per sample in the first week of August which is when the cotton was harvested. Counts declined severely after two weeks. In the kenaf field, whitefly counts peaked to about 1500 per sample in early September, followed by a rapid decline. Fifty leaf samples were also collected along diagonal transects twice a week in all fields. The adults and different stages of immature whiteflies were recorded. Whitefly immatures peaked at about 275 per leaf in early August in the kenaf field. Twenty of the 50 leaves in each batch were collected and placed in black emergence boxes to determine rates of parasitism and composition of the indigenous parasitoid complex. Additional plant measurements included leaf area, dry weight of the leaves, plant height and number of leaves per plant. Other sampling methods used were vacuum and sweep sampling for the adult whiteflies and predators. The long-term objective of this part of the study is to standardize sampling techniques for the different crops being monitored.

The field sites for intensive sampling have also been digitized for incorporation into a GIS database. All insect sampling and meteorological information will be entered into the GIS database to allow researchers to relate actual field sites to all cropping information, including crop production from 1990. An Omnidata® logger is being used to record such weather data as temperature, humidity, leaf wetness, solar radiation and rainfall at half hourly intervals. The USDA-ARS in Weslaco is also developing image analysis techniques in order to computerize the process by which whiteflies will be counted thereby increasing the speed and efficiency of the sampling process.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY REPORT: 1993

FACTORS INFLUENCING WHITEFLY DISTRIBUTION AND COMPARISON OF SAMPLING METHODS IN COTTON FIELDS

Yellow cards (7.6x12.7cm), pan samples, and leaf turns were compared to eggs and nymphs per leaf disc in 24 fields in Maricopa Co. The predictive value of the three sampling techniques, as well as the influence of field slope and adjacent crops on field distributions were determined.

The correlation coefficients for pan samples and leaf turns were higher than coefficients for yellow cards but none were consistent enough to have a predictive value. Less than half of the fields had a significant positive correlation coefficient within sampling dates.

Whitefly counts made at the edge of the field after 1 July were significantly higher than counts made in the field. The number of whiteflies per pan sample dropped with movement into the field and there no differences in samples taken 15, 30, or 60m into the fields. The overall mean numbers of whiteflies per pan sample (21 June to 6 August) at 1 and 15m were 276.5 $\pm$ 44.2, and 84.9 $\pm$ 11.0 respectively.

When fields counts for whitefly at 1m were grouped by slope, fields sloping to the north or south had a average of 800 whiteflies per pan sample on the east side of the fields, but the other sides of the fields had a average of 200 to 400 whiteflies per pan sample. Fields sloping to the east or west had $\approx$ equal pan samples on all sides and capture was less than 200 whiteflies per pan sample. At 15m into the field, there was no difference in mean whitefly counts by direction or slope.

Horizontal sticky yellow cards (7.6x12.7 cm) caught significantly more whiteflies than vertical yellow cards at 0.15 m and 0.61 m elevation. The horizontal yellow cards at 0.15 m caught significantly more whiteflies than any other height or orientation.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY THE REPORT : January 1 - December 1, 1993

DEVELOPMENT AND EVALUATION OF SAMPLING PLANS FOR IMMATURE AND ADULT SWEETPOTATO WHITEFLY IN COTTON

Immatures. Based on results from 1992 we have developed sequential sampling plans for eggs and nymphs based on counting insects on 3.88 cm^2 leaf disk from the second sector of fifth mainstem node leaves. We performed preliminary validation of this sample plan through simulation. This analysis indicated that slightly more, and slightly fewer samples would be needed than prescribed by the plan at densities < 10/disk and > 100/disk, respectively. In 1993 we collected data from a total of 80 field/date combinations in Maricopa, AZ to further validate our sequential sample plan and to develop binomial sampling plans. Additional samples were collected from eight commercial farms west of Phoenix.

Validation of our numerical sequential plans is underway and we are currently developing and evaluating binomial sampling plans based on leaf disks described above. These plans should allow for more time-efficient sampling of eggs and nymphs, especially for decision-making application. Fits of an empirical model ($r^2 > 0.93$) relating mean density/disk to the proportion of infested sample units indicate that when means for eggs and nymphs reach 1.8 and 1.6/disk about 50% of the disks sampled have at least one egg or nymph, respectively. About 95% of the disks are infested when densities of eggs or nymphs reach 16.9 or 11.8/disk, respectively. We are also evaluating tally thresholds > 1 for determining whether a leaf is infested. Analyses of the variances of mean density predictors, error probabilities, cost considerations and economic thresholds, once determined, will be used to evaluate the feasibility of binomial sampling for management application and to select the most efficient tally threshold.

Adults. Within-plant distributions of adults were examined on three occasions during 1993 by counting insects on mainstem leaves from nodes 2 through 7 (terminal = node 1). All counts were conducted in the early morning. Counts from an individual "plant" were generated by censusing a single leaf on each of 6 consecutive plants at a sample site. A total of 244 "plants" were examined. In general the greatest number of adults and the lowest coefficients of variation were associated with counts on leaves from nodes 4-6. We selected counts from the 5th node for further study.

Based on data collected from a total of 64 field/date observations we developed numerical, fixed-precision sequential sampling plans for adult sweetpotato whitefly based on leaf-turn counts from 5th mainstem node leaves. We also evaluated binomial sampling plans using different tally thresholds for determining whether a leaf is infested. This binomial approach should circumvent one of the most significant constraints of leaf-turn counts for population estimation; the necessity of conducting sampling only in the early morning when adult activity is minimal. The fits of an empirical model relating mean density to the proportion of infested sample units yielded high coefficients of determination ($r^2 > 0.92$) for tally thresholds of between 1 and 6 adults per leaf. Analyses of operating characteristic (= probability of error) and average sample number functions indicated that a tally threshold of 3 produced the least error and was most cost-efficient. Binomial sequential sampling stop lines have been formulated for nominal action thresholds of 5, 10 and 15 adults per leaf. Validation of these sample plans are underway.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY REPORT: January 1 - December 1, 1993

COMPARISON OF DIRECT AND INDIRECT SAMPLING METHODS FOR ADULT SWEETPOTATO WHITEFLY IN COTTON

We compared various adult sampling methods for estimating population levels of sweetpotato whitefly adults from 26 May to 23 September, 1993 at Maricopa, AZ. Two primary factors were considered in order to facilitate quantitative comparisons: 1) precision of the estimate relative to the cost of obtaining the information, 2) correlation of estimates with immature population densities. Direct estimates were made by counting the number of adults on the undersides of fifth mainstem node leaves (leaf-turn counts) and using the black-pan method which consists of hitting the tops of 10 plants over an oil coated cake pan. Indirect estimates of density were made using various types and configurations of yellow sticky cards. We evaluated horizontally-oriented 3" x 3" cards at ground level, mid-canopy level and at a level just above the canopy both within fields and approximately 1 m from the edges of fields. We also evaluated vertically-oriented cylinder traps (6" by 3 " diameter) at mid-canopy level and at a level just above the canopy within fields. At 4-6 times during the season, we estimated the cost (=time) required to complete sampling. Taylor's power law was used to describe the mean-variance relationship for the various sampling methods.

In general, all sampling methods indicated a similar pattern of population change over the season. Using estimates of cost per sample unit and determining the number of sample units needed to achieve a precision (SE/mean) of 25% we calculated the cost of sampling for each method. Our analysis of pan and sticky trap methods did not include the cost of materials. Among the sticky trap techniques, horizontally-oriented traps near the ground were most efficient over a wide range of adult densities. In comparison with all horizontal traps, cylindrical traps were at least one order of magnitude less efficient all season. Comparing direct to indirect methods, black pan and leaf-turn counts were much more efficient than the best sticky card methods. Of the direst methods leaf-turn counts were most efficient over a range of densities. Direct methods of estimating adult density (leaf-turn and pan counts) were most highly correlated with immature densities ($r > 0.90$, $n = 36$); however, sticky cards were significantly correlated with immature counts ($r > 0.74$, $n = 36$) prior to, but not following the initiation of insecticide treatments on 3 August. Correlations of direct methods with immature counts were lower, but remained significant ($r > 0.54$, $n = 43$), after insecticide treatments began. Correlations of direct and indirect methods with immature populations sampled the previous week were consistently poorer than those based on sample data collected on the same date.

Overall, considering cost efficiency and the value of the sample information relative to immature densities, our findings suggest that leaf-turn counts would be the best method of estimating adult densities, particularly for management application. This method has the added advantage that there are no additional material costs involved. Horizontal sticky traps, either within or on field edges may be useful in the early-season for detection purposes.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal

DATES COVERED BY REPORT: March 1992-Present

SAMPLING SWEETPOTATO WHITEFLY POPULATIONS IN CANTALOUPES

We are currently developing a binomial sampling plan for adult sweetpotato whitefly (SPW) populations on cantaloupes. Seasonal infestations of SPW in fields of cantaloupes were determined by weekly counts of adults per leaf in several fields near Yuma, Arizona in the spring of 1992 and 1993. We used these data to describe the relationship between mean density of SPW per leaf, m, and proportion of infested leaves, $P_{(I)}$, according to the empirical model $\ln m = a + b \ln[-\ln(1-P_{(I)})]$. This model was used to develop binomial sampling plans based on a presence-absence approach ($P_{(I>0)}$) and for the cutoff value of five ($P_{(I>5)}$) whiteflies per leaf. Three independent data sets from 1993 were used to evaluate the models generated. The presence-absence approach yielded the best agreement between data and model, although plans based on the higher density thresholds had a lower variability. Both models gave best predictions at low infestation levels, and some of the higher m values were overestimated. Because the tentative economic threshold for SPW on cantaloupes is three adults per leaf, which corresponds to low $P_{(I)}$ values, the binomial sampling plan was reliable for pest management purposes.

We have also been investigating the population dynamics of SPW in an effort to describe their spatial distribution and aggregation patterns on cantaloupes. In studies similar to above, infestations of SPW were measured by direct counts of eggs, nymphs, and adults. All stages were sampled from leaves at the terminal and crown portions of the plant. Adults were sampled at 0700 and 1300 h on the entire leaf, and immature stages were counted in a 1-cm^2 area from each of four quadrants of a leaf. Adult whiteflies were more abundant on samples conducted on terminal leaves at 0700 h in all fields. There were no differences between leaf sections for any immature life stage, but nymphs were more abundant on crown leaves, whereas eggs had higher densities on terminal leaves. The Power Law, the Patchiness Regression, and Morisita index indicated that all life stages were aggregated between leaf positions. Stop lines for sequential sampling plans calculated from Kuno's and Green's methods were considerably different between terminal and crown leaf position suggesting that sampling sites within a plant should be carefully considered for sequential sampling plans.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal

DATES COVERED BY REPORT: January - December 1993

POPULATION DYNAMICS OF *BEMISIA TABACI* IN CANTALOUPE

Infestations of *Bemisia tabaci* (Gennadius) in fields of cantaloupe, *Cucumis melo* L., near Yuma, AZ, were measured by direct counts of eggs, first to third instar nymphs, fourth instar ("red-eyed") nymphs and adults. All stages were sampled from leaves at the terminal and crown portions of the plant. Adults were sampled at 0700 and 1300 h on the entire leaf, and immature stages were counted in a 1-cm^2 area from each of four quadrants of a leaf. Adult whiteflies were more abundant on samples collected at 0700 h and on terminal leaves in all fields. There were no significant differences between leaf sections for any immature life stage, but all nymphs were more abundant on terminal leaves, whereas eggs had higher densities on crown leaves. The Power Law, the Patchiness Regression, and the Morisita index indicated that all life stages were aggregated, but there were distinct degrees of aggregation between leaf positions. For all life stages, stop lines for and Green's methods were considerably different between leaf positions. The performance of the three methods suggested that the Morisita index is more adequate than the Power Law or the Patchiness Regression to describe aggregation levels of a population.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics and Dispersal

DATES COVERED BY REPORT: 1992-1993

SILVERLEAF WHITEFLY ON CROPS AND WEEDS IN THE IMPERIAL VALLEY

Since April, 1992, we have monitored silverleaf whitefly densities on 20 crops and 40 weed species in the Imperial Valley of California in order to describe the whitefly's seasonality and host range. Data collected included nymphal density, based on timed counts in the field, and mortality and parasitization which were determined microscopically.

By far the highest whitefly densities were found on crop plants. Late season spring melons, cotton from July through harvest, and fall melons had the largest numbers followed by cole crops from September through December. The average density on alfalfa was low, but a few fields harbored high levels of whiteflies from July into October. Among other major crops, almost no whiteflies were found on lettuce and sugar beets. Seasonality of whitefly infestations was similar between the 2 sampling years.

Among sampled weeds, velvetleaf sustained the highest whitefly levels, but the plant is not as abundant as several other weeds. Wright groundcherry, sowthistle, and sunflower had high to moderate counts. Lower or more sporadic populations were found on alkali sida, bindweed, London rocket, malva, pigweed, silverleaf nightshade, and telegraph weed.

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DATES COVERED BY REPORT: 1993

MATING BEHAVIOR AND COMPETITIVE DISPLACEMENT IN WHITEFLIES

The silverleaf whitefly (SLWF), *Bemisia argentifolii*, Bellows and Perring, although similar in gross morphology to the sweetpotato whitefly (SPWF), *Bemisia tabaci* (Gennadius), differs in the following ways: 1) SLWF lays more eggs; 2) SLWF has a higher feeding rate; 3) SLWF causes physiological disorders in plants such as squash silverleaf, tomato irregular ripening, and light stalk in broccoli; 4) SLWF is a poor transmitter of lettuce infectious yellows virus, whereas SPWF is an efficient transmitter; 5) SLWF has a broader host range than does the SPWF; 6) there are genetic difference between the two species; 7) there are fine morphological differences between the species.

In the three years that the silverleaf whitefly has been known to exist in the southern desert agricultural areas, it has displaced SPWF. In fact, surveys have indicated that SPWF no longer is present in the United States. This displacement, in the short amount of time that the SLWF has been known to exist in the U.S. (since 1986), is unusual and has caused entomologists across the country to question if the SLWF is actually a new species or is an interbreeding strain which has cross-bred with the SPWF, effectively breeding it out of existence.

We have conducted research to elucidate mechanisms responsible for the displacement of SPWF by SLWF. The expanded host range of SLWF enables it to overwinter in the southern deserts on cole crops (broccoli, cauliflower, cabbage) where SLWF overwintered on a limited number of weed hosts. We have analyzed trap data from 1987 (prior to SLWF introduction) and 1991 (after SLWF introduction) which documents numbers of SLWF far exceeding those of SPWF. This disparity, heavily favoring SLWF, gives it a competitive edge going into the spring melon season.

Additionally, in mating studies we have documented courtship behavior (determined by parallel orientation of males and females) between the two species, however no copulation takes place. Further analysis has shown that SPWF males and females spend less than 1/3 the amount of time in precopulatory courtship behavior than do SLWF males and females. This difference becomes critical when the two species are in mixed populations, as would have been the situation when SLWF was introduced into California. When SLWF males are placed with SPWF females, they will court the female for an average of 43 minutes before courtship is terminated. Conversely, SPWF males will court SLWF females for an average of only 18 minutes before courtship is terminated. Thus SLWF males, by the nature of their species having longer courtships prior to copulation, effectively block courtship and mating of SPWF females by SPWF males.

Our data show large differences between overwintering densities of SPWF and SLWF in addition to mating disruption of SPWF females by SLWF males. These results, combined with the differences between the two species outlined above (higher numbers of eggs laid by SLWF, a more aggressive feeding rate of SLWF, and the fact that all hosts of SPWF also are hosts for SLWF), have led us to conclude that there has been a displacement of the SPWF in our desert agricultural regions by the SLWF.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal

DATES COVERED BY REPORT: 1992-1993

FIELD EXAMINATION OF MIGRATION BY *BEMISIA TABACI*

In 1992 and 1993 we attempted to verify laboratory observations with field-generated data. Statements were made in the past that whiteflies were not very effective fliers, because it had never been established that whiteflies engaged in long-range migration. They were also thought to be limited in this regard by their small size (which would increase the possibility of desiccation and restrict the amount of energy reserves). In earlier reports, whiteflies were captured at distances of up to 12 km from their point of origin. These studies employed sticky traps, and no attempt was made to determine whether captured whiteflies were alive or dead. We believe that "effective migration" results only when insects relocate to new habitats and are capable of establishing new colonies. Our studies in 1992 and 1993 were designed to establish the effective migrational range of *B. tabaci*. In these studies, we marked whiteflies in the field with Day-Glo® dust. Laboratory studies showed this had no effect on flight behavior if applied 12 h prior to trapping the whiteflies. Small suction traps were placed at varying distances from the dusted field in 1992 (up to a km) and up to 3 km in 1993. Whiteflies caught in these traps were examined to determine if they originated in the marked fields, checked to see if they were alive, and their reproductive capacity was measured.

On several of our sampling dates live marked whiteflies were captured in traps 1000 m from the source field. Based on this preliminary trap catch data, we believed that the effective migrational range of *B. tabaci* might be several-fold greater than this value. Additionally, prevailing wind direction and trap catches were highly correlated. Field studies in 1992 provided new insight into the ability of whiteflies as potential colonizers. Distance traveled had no significant effect on adult female longevity. Several whiteflies collected in fan traps 1000 m from the source lived > 27 days in clip cages on melon leaves in a greenhouse. Female whiteflies collected from all distances were capable of producing offspring immediately.

Preliminary analysis of weather patterns in 1993 indicated that prevailing winds in the early morning in the Yuma Valley were from the northeast and followed cold air drainages. In July and August marked whiteflies were collected in traps as far as 2.0 km from the source field. A geographic information system (GIS), which is a computer database that organizes information in a spatial framework, was used for data analysis. GeoEAS, a public domain software package (US Environmental Protection Agency) was used for the geostatistical analysis of the whitefly distribution data. The analysis included examination of histograms, creating new variables using indicator transformations at various cutoff values, examining sample variograms with and without directional limits, and calculation of moving spatial averages using block kriging of the indicator transformed variables. In September and October additional traps were placed as far as 3.0 km from the source field. Marked whiteflies also were collected in the most distant of these traps. These field results support our hypothesis that more whitefly movement in the fall in the Yuma Valley is in a SW direction (prevailing winds are from the NE). Within a 3-hr time period whiteflies can travel as far as 3.0 km from the source field. However, only a few marked whiteflies were trapped at this distance. A better estimate of the effective migrational range of *B. tabaci* may be 2.5 km. We examined the effects of female flight distance and egg load and found significant differences in the egg load of field collected whiteflies versus whiteflies collected in traps at all distances from the source field. No relationship, however, was identified between distance flown and egg load.

INVESTIGATOR'S NAME(S): David G. Riley

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal

DATES COVERED BY REPORT: January 1993 - December 1993

THRESHOLDS OF WHITEFLIES IN MELONS

The effect of the b-strain sweetpotato whitefly (SPWF) on melons was quantified in 1992 and 1993. An increase in total numbers of immature SPWF was associated with a decline in harvested melon weight, a decline in number of boxes, and increase in the size category number or number of fruit per box (which means a decrease in fruit size), a decrease in sugars, and increases in sooty mold and downy mildew. The relationship of different stages of SPWF with yield parameters suggest that SPWF large nymphs provide a better indicator of SPWF effects on yield than adults. The threshold treatments tested included three thresholds for nymphs and three for adults: (1) 0.5 large nymphs/7.6 cm^2, (2) 1 large nymph/7.6 cm^2, (3) 2 nymphs/7.6 cm^2 of leaf area, (4) 1 adult per leaf, (5) 3 adults per leaf, (6) 6 adults per leaf, (7) weekly sprays, and (8) an untreated check. The best threshold treatment tested was 0.5 large nymphs per 7.6 cm^2 of leaf area. Using this threshold imidacloprid applications resulted in a 40% increase in net return and resulted in a total of 0.25 lb AI/acre of material used.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal.

DATES COVERED BY REPORT: 1993

PRELIMINARY RESULTS OF AN INTENDED HOST-FREE PERIOD IN DIFFERENT NORTHWESTERN DOMINICAN TOMATO GROWING AREAS ON THE POPULATION DYNAMICS OF WHITEFLIES AND THE INCIDENCE OF GEMINIVIRUS

Since the appearance of at least one whitefly-transmitted tomato geminivirus in growing areas of the northwestern Dominican Republic in 1991, severe yield losses as well as an important reduction and abandonment of the processing-tomato growing areas have been reported. As a consequence, the ministry of agriculture ordered a whitefly-host free period during June, July and August of 1993. The decree was not rigorously practiced in many places. During the growing season 1993/94 the uncharacterized tomato geminivirus showed a high incidence in most of the monitored fields of about 15 locations. Anyhow, several fields sown during the month of August showed a delay in virus infestation and obtained relatively satisfactory yields. Low whitefly levels observed in most of the nursery beds and recently transplanted fields however, were followed by a heavy virus infestation up to 100% during the ripening of fruits. Insufficient control practices did not avoid an early virus infestation in most of the fields. Parasitism by naturally occurring species has been relatively low during the critical period. The buildup of high predator populations, mainly of mirid bugs, *engytatus* (=*Cyrtopeltis*) *tenuis* and *E. modestus*, spiders and coccinelids takes several weeks and has been disturbed by chemical whitefly control.

The preliminary results of the monitoring of whiteflies and the incidence of geminivirus do not permit conclusions about the main sources of the tomato geminivirus, yet. Anyhow, the host-free period has to be considered as a prerequisite for an integrated approach to reduce yield losses caused by these agents and their vectors to acceptable levels. Practical biocontrol methods are not available at present and will have to face extremely low thresholds during the first weeks of the crop.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal

DATES COVERED BY REPORT: January-December 1993

IMPACT OF PESTICIDE APPLICATIONS ON THE DISTRIBUTION OF *BEMISIA TABACI*

We measured the effect of insecticide applications on the distribution patterns of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), in fields of cantaloupe, *Cucumis melo* L., in Yuma, AZ. Whitefly infestations were measured by direct counts of adults, eggs, first to third instar nymphs, and fourth instar ("red-eyed") nymphs. Adults were sampled on the entire leaf, and the number of immature stages was counted in a 1-cm^2 area of a leaf. The indices b (Power Law), β (Patchiness Regression), and 1_d (Morisita index) indicated that all life stages were aggregated, and there were distinct degrees of aggregation between treatments for most comparisons. However, results for the three indices were not similar for determining the relative aggregation levels between treatments. The index b indicated that populations on untreated fields were more aggregated than those in sprayed plots. The index I_d had opposite outcome, and results of β were variable. The Morisita index was sensitive to a few unusually high means among a series of low densities in the treatment plots, which could be attributed to refugia resulting from failure in the insecticide application. Such pattern was not detected by the indices b or β. Despite the usefulness of the Power Law and Patchiness Regression for describing the relationship between spatial or temporal variability and mean densities, we suggest that the Morisita Index is more appropriate for describing spatial distribution because it is based on a precise definition of aggregation.

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RESEARCH & IMPLEMENTATION AREA: Section A: Ecology, Population Dynamics, and Dispersal.

DATES COVERED BY REPORT: 1993

TEMPERATURE-DEPENDENT REPRODUCTION OF SWEETPOTATO WHITEFLY ON COTTON

Reproduction of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), was studied on DES 119 cotton at 19 constant temperatures during May-July 1993. Newly emerged adults were held in arenas on the underside of seedling leaves, and the number of eggs laid each day was recorded for each female. Average daily oviposition per female was calculated as the total number of eggs laid by all females within a treatment divided by the number of females alive each day. Total eggs per female were calculated as the sum of the daily averages. Oviposition occurred at all temperatures studied from 15.3 to 37.2°C. The rate of oviposition varied with female age, and at all but the coolest temperature, the average number of eggs deposited per female per day formed a skewed-right pattern. A uniform daily oviposition pattern was observed at 15.3°C. On average, females laid as many as 280 eggs at 18°C, and as few as 44 and 5 eggs at 15.3 and 37.2°C, respectively. Total fecundity was also influenced by eclosion date, with more eggs laid by females emerging in May than July, even at similar temperatures. This result may involve a general reduction in female size as rearing temperatures increased from May to July. The data from this study will form the foundation for modeling reproduction of the "B" strain of *B. tabaci*.

TABLE A. Summary of Research Progress for Section A, Ecology, Population Dynamics, and Dispersal, in Relation to Years 1 and 2 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
A.1 Define biology, phenology, and demography of SPW on greenhouse, field crop and wild host plants.	Yr. 2: Identify preferred hosts, determine seasonal distribution, determine developmental, reproductive and mortality rates of SPW on crop and weed hosts.	X		Information gathered on the seasonal population dynamics of the whitefly in the San Joaquin and Sacramento Valleys of California and the Lower Rio Grande Valley of Texas identified important hosts and quantified their contribution to regional whitefly populations. Information on the host preferences of the whitefly will potentially permit crop arrangement and sequencing to limit whitefly buildup over a growing season. Studies on the range of temperatures over which the whitefly can oviposit will allow researchers to better understand the population dynamics of the whitefly relative to various climatic conditions (from Florida to Hawaii).
A.2 Develop efficient SPW sampling plans for research and decision making purposes.	Yr. 2: Formulate sampling plans, determine relationship between sampling techniques for adults and crop infestations, evaluate feasibility of a standard sampling technique.	X		Significant progress was made in development of sampling techniques in cotton and melons. The relationships between the numbers of whitefly adults present in an area and the numbers of immature whiteflies infesting a crop were quantified, thereby permitting estimations of whitefly infestations based on adult counts. The development of sequential and binomial sampling techniques will permit rapid estimations of whitefly densities with minimum time and processing costs. Development of effective sampling programs will permit researchers to document the impact of management tactics on the whitefly, and subsequently permit crop managers to implement whitefly controls at critical times. A weakness still exists in the lack of a standardized sampling technique within and among crops across the U.S.
A.3 Develop economic thresholds for SPW in relation to feeding damage, honeydew production and virus transmission.	Yr. 2: Determine and quantify relationships between SPW population density and plant yield and quality, formulate economic thresholds in relation to sampling protocols.	X		Relationships between whitefly infestations and the yields and quality of cotton, kai choy and cantaloupe were established. This information is essential to the development of action and economic thresholds that will provides growers with a basis to time their management techniques so as to limit economic losses while conserving chemical controls. Action thresholds for adult whitefly have been incorporated in binomial sampling plans in cotton and melons for efficient implementation in the field. Given the numerous crops infested by the whitefly, there is a tremendous need to establish this information for many more crops. Important research is still lacking on the relationship between whitefly density and viral disease problems.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
A.4 Develop and test population models to describe and predict SPW dynamics.	Yr. 2: Develop relationships between SPW biology and crop phenology and crop sequencing. Integrate SPW, natural enemy, and plant components into simulation models.	X		Models were developed to examine the interactions among the whitefly and its natural enemies as well as the movement and reproduction of the whitefly over regional cropping areas (the San Joaquin Valley and Imperial Valley of California, the Lower Rio Grande Valley, Texas and in South Florida). Models examining interactions among the pest and its natural enemies will provide insights into the implementation of biological control. Regional studies may provide insights into the yearly patterns of whitefly infestation by permitting the identification of early season foci for whitefly buildup, and the subsequent spread of whiteflies from these foci to susceptible crops.
A.5 Determine factors influencing SPW dispersal and impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems. (Combined with A.6 based on Year 1 recommendations)	Yr. 2: Determine biological factors (physiology, behavior, sex, etc.) influencing dispersal.	X		Several factors influencing short and long-range whitefly dispersal have been determined including plant phenology, plant amino acid content, abiotic factors (diurnal cycles, temperature, light, wind) and physiological and morphological conditions of the whitefly. Additionally, the potential distances achieved by migrating whiteflies have been estimated. This information provides insights into the reasons why whiteflies move within and among crops, and can lead to optimum crop arrangement and sequencing to reduce the impact of whitefly immigrations on affected plantings.
A.6 Determine impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems.	Yr. 2: Combined with A.5.	X		

RESEARCH SUMMARY

Section A: Ecology, Population Dynamics and Dispersal

Compiled by
S. E. Naranjo & M. W. Johnson

The information in this Research Summary is based upon the compilation of abstracts received no later than the deadline of February 14, 1994.

A.1 Define biology, phenology, and demography of *B. tabaci* Strain B on greenhouse, field crop and wild host plants.

Considerable progress was achieved under this objective relative to Year 2 goals. Work on host preference was conducted in several states. Laboratory work in California indicated that in choice tests *Bemisia tabaci* Strain A and *B. tabaci* Strain B (= Silverleaf whitefly) laid proportionally more eggs on zucchini than cabbage and sugar beets. *B. tabaci* Strain A preferred sugar beets over cabbage while the opposite was true for Strain B whitefly. In general, both whitefly strains preferred to oviposit on plants that enhanced nymphal survivorship and allowed the shortest developmental times. Host preference studies on cantaloupe, cotton, broccoli and lettuce in Arizona indicated that *B. tabaci* Strain B host preference was related to the abundance of vascular bundles in the leaf tissues of the various plant hosts. Vascular bundles in these plant hosts are closer to the underside leaf surface as compared to the upper leaf surface, and, thus, may influence whitefly orientation to the leaf.

Research in Arizona showed that phosphorus deficiency reduced oviposition on young cotton leaves, but did not affect attractiveness of cotton cotyledons. Further, host acceptance was associated with low leaf sucrose concentration and high leaf water potential. This suggests that conditions that impact plant osmotic potential may have a major impact on cotton susceptibility. Geotropic responses influence whitefly oviposition in most
crops.

With respect to seasonal distribution, data were collected on 23 crops and >50 weed hosts in several counties in the San Joaquin Valley, CA. *B. tabaci* Strain B was distributed throughout the southern end of the San Joaquin Valley, but was not found in counties in the more northern Sacramento Valley. These results indicate that the whitefly has a broad host range in the San Joaquin Valley, but that its distribution is limited to the southern portions of California. Population dynamics of the whitefly was assessed in nine cotton plantings and one kenaf planting in the lower Rio Grande Valley of Texas. Densities of whiteflies in cotton peaked in August, corresponding to harvest whereas in kenaf densities peaked in September.

Laboratory work in California indicated that *B. tabaci* Strain A and *B. tabaci* Strain B survived best on zucchini and poorest on sugar beet with survival on cabbage intermediate. This indicates that the fitness of the whitefly varies with plant host. Laboratory work in Mississippi showed that *B. tabaci* Strain B laid eggs on cotton at temperatures from 15.3 to 37.2°C. Total fecundity was influenced by eclosion date with more eggs laid by females emerging in May than July, even at similar temperatures.

A.2 Develop efficient *B. tabaci* Strain B sampling plans for research and decision making purposes.

Efforts were made in cotton and melons to formulate sampling plans. Based on an understanding of underlying spatial distributions, sequential and binomial sampling plans were developed for *B. tabaci* Strain B immatures and adults infesting cotton in Arizona. Plans were based on use of the fifth mainstem node leaf as the sample site. Validation of these plans is underway. Studies in California examined the within

plant distribution of whitefly stages on cotton, and the results generally agreed with those reported from Arizona. Whiteflies infesting cantaloupe plantings in Arizona were found to have an aggregated distribution in all life stages when sampled relative to individual leaves. Adult and nymphal whiteflies were most abundant on terminal leaves compared to the eggs which were more abundant on the crown leaves. Aggregation of all life stages changed depending on the leaf position sampled. Depending on the sampling indices used, changes in whitefly aggregation were observed following pesticide applications to sampled plots. The Morisita Index was recommended as the optimum model for describing the spatial distribution in melon given its precise definition of aggregation. A binomial sampling plan is being developed for adult whiteflies in melons.

Success was achieved in several studies in determining the relationship between sampling techniques for adults and crop infestations. Various sampling techniques were evaluated in cotton in Arizona to relate adult whitefly densities to immature whitefly densities within a field. Direct estimates were made by counting adults on leaf undersides at the fifth mainstem node (leaf-turn counts) and by striking plant tops held over a black pan coated with oil. Indirect counts involved various sticky traps positioned at various angles and levels within and at the edge of the crop. Direct counts of adults were most highly correlated with immature counts and in contrast to sticky cards these correlations remained significant following insecticide applications. Leaf-turn counts appeared to be the most reliable and cost-effective method for whitefly monitoring in cotton. Additional studies in Arizona indicated that a definite edge effect occurs with *B. tabaci* Strain B with greater numbers of individuals recorded at field edges compared to counts within fields. Slope orientation of fields also affected the numbers of whiteflies captured with greater numbers of whiteflies caught on east sides than west sides of plantings in fields sloping from north to south.

To date, no standard sampling technique has been adopted across the states for any crop. Lack of a standard technique for a given crop prevents direct comparisons of management techniques and population ecology studies based on different sampling techniques.

A.3 Develop economic thresholds for *B. tabaci* Strain B in relation to feeding damage, honeydew production and virus transmission.

Several studies determined relationships between *B. tabaci* Strain B population density and plant yield and quality. The relationship between *B. tabaci* Strain B densities and cotton lint yield was determined in Arizona based on field studies. Lint yields were negatively correlated to all whitefly stages with the best regression values associated with seasonal average nymphal densities ($r = 0.90$). Studies on cotton in the Imperial Valley, California indicated that high *B. tabaci* Strain B populations were negatively correlated with cotton lint yields and positively correlated with lint stickiness. Densities of whitefly associated with maximal yield were estimated for egg, nymphal, and pupal densities and for adults captured on yellow sticky traps. Laboratory studies in Hawaii showed that high densities of *B. tabaci* Strain B immatures reduced lettuce and kai choy growth. Additionally, kai choy plants exposed to $>$ 10 adult whiteflies and their subsequent offspring for 3 weeks developed symptoms of stem blanching and leaf curling on new growth. Only immatures were involved in the production of symptom development.

Several studies have formulated action thresholds for adult whiteflies in relation to sampling protocols. Binomial sampling plans have been developing in cotton and melon which allow treatment decisions to be made based on the proportion of infested leaves. The impact of *B. tabaci* Strain B on cantaloupe yield was determined in Texas. Cantaloupe yields (quantity and quality) were negatively correlated with immature *B. tabaci* Strain B densities. High densities of *B. tabaci* Strain B caused decreases in fruit weight, size and fruit sugar content, and increased incidence of sooty mold and downy mildew. The best threshold treatment on cantaloupe was 0.5 large *B. tabaci* Strain B nymphs per 7.6 cm^2 of leaf area.

These results are encouraging because they indicate that the whitefly does not have to be maintained at a zero tolerance level. However, it must be noted that levels causing plant injury are low and may limit the use of biological control unless the natural enemies are highly effective.

A.4 Develop and test population models to describe and predict *B. tabaci* Strain B dynamics.

Efforts are underway to develop quantitative descriptions of the relationships between *B. tabaci* Strain B biology, and crop phenology and crop sequencing. Researchers from Florida, Arizona, California and Texas are developing models to simulate *B. tabaci* Strain B movement and reproduction over large areas (1-100 miles) in regional cropping areas. *B. tabaci* Strain B movements involve short-range diffusive movement (1-100 m) and long-range migratory movement (1-5 km). The latter movement appears to be influenced by crop senescence. Efforts are underway to examine the influence of host sequencing and spatial patterning on *B. tabaci* Strain B populations in the San Joaquin Valley and Imperial Valley of California, the Lower Rio Grande Valley, Texas and in South Florida. These studies may provide insights into the yearly patterns of whitefly infestation by permitting the identification of early season foci for whitefly buildup, and the subsequent spread of whiteflies from these foci to susceptible crops.

Workers in Arizona are developing a model to simulate whitefly/parasitoid/predator population dynamics and interactions in the cotton system. The model integrates the component processes of natality, development and mortality. In Texas, a model is being developed to simulate interactions between *B. tabaci* Strain B and two associated natural enemies: *Encarsia pergandiella* (autoparasitoid) and *Paecilomyces fumosoroseus* (fungal pathogen). Among various parameters being investigated are the influence of the autoparasitism on whitefly/parasitoid population stability and the influence of temperature and humidity on whitefly/fungal pathogen interactions. A greater understanding of the interactions of the whitefly and its biological control agents will provide insights into the implementation of biological control.

A.5 Determine factors influencing *B. tabaci* Strain B dispersal and impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems. (Combined with A.6 based on Year 1 recommendations)

Efforts continue to in the study of biological factors (physiology, behavior, sex, etc.) influencing dispersal. Workers in Arizona found associations between amino acid concentration in melons and the numbers of eggs laid by the *B. tabaci* Strain B. As plants aged, the number of eggs laid per female increased disproportionately to the increase in total amino acids. Females with > 4 mature eggs were reluctant to fly, whereas, females with fewer eggs were prone to long-range dispersal flights. In greenhouse studies, it was found that whiteflies exhibited a positive phototactic response to sky light. Temperature could be used to predict the response. This information can provide insights into the development of cultural controls targeting reductions in whitefly movement among crops.

Field research in Arizona utilizing marked individuals showed that *B. tabaci* Strain B adults could move 3 km from a source. This movement was influenced by prevailing wind conditions and did not negatively impact whitefly longevity. The ability of viable whiteflies to travel such distances was previously unknown and underscores the need for community efforts in managing the whitefly.

Workers in California and Arizona determined diurnal flight activity of *B. tabaci* Strain B with respect to meteorological conditions. Under calm conditions, *B. tabaci* Strain B flight activity peaked in mid-morning in contrast to the lack of a definable peak under windy conditions. Densities of *B. tabaci* Strain B tended to build up on crop edges facing prevailing winds.

No results were obtained with respect to quantifying seasonal intercrop and weed movement. However, the information generated in Year 2 should provide methodologies applicable to this area of concern.

B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Vector Interactions

Chairs: Richard T. Mayer and Judith K. Brown

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RESEARCH & IMPLEMENTATION AREA: Section B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: 1992-1993.

A COMPARISON OF PARTIAL SEQUENCES FROM SELECTED GEMINIVIRUSES NATURALLY INFECTING WEEDS AND CROPS IN FLORIDA.

Recently with the establishment (1986) of the "B" biotype whitefly (*Bemisia tabaci*) in Florida, whitefly-transmitted geminiviruses have been identified as new, serious pathogens infecting tomatoes, (1989), cabbage (1990), and beans (1993) in Florida. Prior to this whitefly invasion, many weeds widespread in Florida with symptoms characteristic of geminivirus infection were observed.

In order to identify the possible origin of the geminiviruses infecting crop plants in Florida, we studied the relationships (sequences of selected areas of the genome) of these geminiviruses with the geminiviruses in weeds in Florida and with geminiviruses in Latin America.

Segments of DNA-A (ALI 1978- 496 AR1, about 1.1 kb) and of DNA-B (BLl 2039- 2 common region [CR], about 0.6 kb) were amplified by PCR and cloned from naturally, geminivirus infected weeds (*Sida* spp.), collected from North/Central (Gainesville) and South Florida (Homestead) and from infected beans north of Gainesville. The nucleotide sequences of the selected geminiviruses were compared by alignment with previously sequenced tomato mottle virus (TMoV), and with a geminivirus (MaGV-FI-) infecting *Macroptilium lathyroides* in Homestead. The resulting alignment of the open reading frames (ORFs) and CRs showed a high sequence homology of the *Sida* isolates with TMoV and with the geminivirus infecting beans near Gainesville. The geminivirus infecting beans in South Florida (Homestead) was very closely related to the bean golden mosaic virus (BGMV) type II isolates found in the Caribbean region and Central and South America. The MaGV-FL isolate showed a more distant relationship to BGMV type II isolates. Comparisons of the hypervariable region sequences of the component B, which are presumably under different evolutionary selection pressure, as they show greater divergence than the ORFs, showed a low level of sequence identity. These studies may provide information regarding the origin of the new geminiviruses infecting crops in Florida.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, biochemistry, biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: 1992-1993

DESCRIPTION OF A SPECIES OF *BEMISIA*

Bemisia argentifolii Bellows & Perring, n. sp., is described from material collected in California and Florida. This species has been referred to elsewhere as *B. tabaci* strain B, or *B. tabaci* poinsettia strain. The species has been demonstrated to be distinct from *B. tabaci* by crossing experiments, studies on intraspecific and interspecific mating behavior, analysis of allozymic frequencies, PCR analysis of genomic DNA, and morphological evaluation. The description of the new species is based on morphological and allozymic characters. The species is distinguished from *B. tabaci* in the fourth nymphal instar by the absence of a dorsal seta, the width of the thoracic tracheal folds, the width of the wax extrusions from the tracheal folds, and by migration distances of allozymes for three enzyme systems.

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RESEARCH & IMPLEMENTATION AREA: Section B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: Research conducted from January-December 1993.

DETECTION AND IDENTIFICATION OF WHITEFLY-TRANSMITTED GEMINIVIRUSES BY POLYMERASE CHAIN REACTION (PCR)

Polymerase chain reaction methods have been applied to the investigation of over 60 isolates of whitefly-transmitted (WFT) geminiviruses from Old and New World sites. A 600 bp fragment of the coat protein gene was amplified and sequenced in order to investigate the utility of the capsid protein as a determinant of virus properties relevant to pathogenesis and virus-vector interactions. Nucleotide and deduced amino acid sequence data will be used to investigate the diversity among virus capsid protein genes for purposes of delineating virus relationships, defining virus-vector specificity, and potentially for developing predictive strategies for virus resistance. A database containing these sequences has been established, and additional sequences will be entered as they become available. This will facilitate rapid comparisons between geminivirus isolates and assist in accurate geminivirus identification, a capability not previously available. Geminiviruses from the US, Mexico, the Caribbean Basin, and Central America are presently under intense investigation in order to evaluate the distribution of this relatively new group of plant viruses. In addition, the data can be used to assess the relative variability between WFT geminiviruses in geographically distinct, but adjacent regions of the Western Hemisphere, based on an analysis of a putative key region of the viral coat protein gene.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: January 1993 - November 1993.

IDENTIFICATION AND OCCURRENCE OF THE SURFACE LIPIDS AND WAX PARTICLES OF THE ADULT WHITEFLIES, *BEMISIA TABACI* AND *TRIALEURODES VAPORARIORUM.*

Adult whiteflies are notable in that they and their surrounding surfaces are covered with copious amounts of wax particles covering all body surfaces except the eyes. The surface lipids and the wax particles, of the adult whiteflies of *B. tabaci* biotypes A and B, and *T. vaporariorum* were characterized. No differentiating components were found in the external lipids of biotypes A and B. At eclosion there were similar but small amounts of long-chain hydrocarbons, aldehydes, alcohols and wax esters on *T. vaporariorum*. *B. tabaci* had a similar complement of lipid classes but without the wax esters. Long-chain aldehydes and long-chain alcohols were the major lipid classes synthesized post-eclosion and there was a slight increase in the amount of wax esters. Within a few hours long-chain aldehydes and long-chain alcohols were the dominant surface lipid components, with chain lengths of C_{34} on *B. tabaci* and C_{32} on *T. vaporariorum*. Hydrocarbons, mainly *n*-alkanes, were minor components of the surface lipids.

The major wax esters were C_{46} on *B. tabaci* and C_{42} on *T. vaporariorum*. The composition of the individual peaks of wax esters analyzed by gas chromatography-mass spectrometry was determined by analyzing the mass spectral data with single ion monitoring. The major acid and alcohol moieties in the wax esters of *B. tabaci* were C_{20} and C_{26}, respectively, and of *T. vaporariorum* were C_{20} and C_{22}, respectively.

The wax particles were collected from the surfaces of *B. tabaci* and *T. vaporariorum* by gently bouncing the flies individually on a cover glass slip. The major components of the wax particles from *B. tabaci* were a C_{34} aldehyde and a C_{34} alcohol plus small amounts of C_{32} aldehyde and alcohol. The major components of the wax particles from *T. vaporariorum* were a C_{32} aldehyde and a C_{32} alcohol plus small amounts of C_{30} aldehyde and alcohol. The aldehyde:alcohol ratio of the wax particles was estimated as approximately 2:1. There were essentially no wax esters or hydrocarbons associated with the wax particles.

The deposition of wax esters on the cuticular surface occurred during the period of formation of the wax particles. Analysis of surface lipids of the wings indicated that the wing surfaces were a major site of deposition of wax esters. We observed no obvious differences in the composition of the external lipids with respect to sex or host plant.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research-Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Virus Vector Interactions

DATES COVERED BY REPORT: January 1, 1993 - November 30, 1993

PARTIAL CHARACTERIZATION AND TRANSMISSION BY THE SILVERLEAF WHITEFLY OF A NEW DISEASE OF LETTUCE

In the winter of 1992-93 in the Imperial Valley, moderate to high proportions of plants in some iceberg lettuce fields showed yellowing and stunting characteristic of lettuce infectious yellows virus (LIYV). However, samples from these fields that were tested at both UC Riverside and Davis failed to give a positive reading for LIYV. Whitefly transmission experiments using adults from a *Bemisia tabaci* 'Type B' colony were attempted. Following a 48 hr. inoculation access period, all plants were treated by foliar spray with bifenthrin, followed by treatment with the systemic insecticide admire. Results from three greenhouse experiments indicated efficient transmission of an infectious agent from symptomatic yellow plants to young, healthy lettuce. Further investigation using dsRNA analysis revealed the presence of an RNA virus in symptomatic lettuce plants but not in healthy lettuce. These findings suggest the presence of a whitefly-transmitted RNA virus that infects lettuce, but that is different from LIYV.

This fall (1993), a field experiment was established using four commercial cultivars of lettuce planted on three different dates (two week intervals). At this writing, yellowing and stunting is most evident in the 'Emprire' plots planted on the earliest date, but is also apparent in 'Merit 88' and 'Vanguard 75' varieties. Symptoms of infected plants will become more visible as the lettuce plants mature.

Further work in the greenhouse showed a number of plant species in the genus Nicotiana are readily infected by the putative virus, displaying distinctive yellowing especially in older leaves. Now that a plant host other than lettuce has been determined, efforts are being mounted to increase the putative virus in that host for purification. If successful, a serological detection assay will be developed for further investigations in the field.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: 1993

SWEETPOTATO WHITEFLY HOST PREFERENCE AND LEAF HABITAT ORIENTATION

Studies on the host preference of sweetpotato whitefly B strain (SPW), *Bemisia tabaci* Gennadius, for cantaloupe, cotton, broccoli, and lettuce and factors affecting top and underside leaf habitat were conducted in the Imperial Valley, CA in laboratory, greenhouse and field studies in 1992-93. Results of choice tests showed that SPW prefer cantaloupe followed in order by cotton, broccoli and lettuce. In choice tests when cantaloupe was not present, SPW preferred cotton to broccoli and lettuce. In some instances it appeared that broccoli attracted more adults and sometimes had higher numbers of eggs as compared to cotton in the field. Our studies suggest that host preference of SPW to the four plant species was related to the abundance of vascular bundles in the different plant species leaf tissues. Total length of vascular bundles per unit of leaf volume was about 50% greater in cantaloupe than in cotton. Vascular bundle lengths per unit of leaf volume in cotton and broccoli exceeded those of lettuce by two-fold. Field studies showed that SPW infestations occur predominantly on the underside leaf surfaces. However, infestations also occur on the upperside of leaf surfaces. The distance from upperside and underside leaf surfaces to the nearest vascular bundles in the cotton leaves were 131 and 60 μm, respectively, suggesting a possible reason for underside leaf habitat preference. Other factors that may contribute to the underleaf habitat behavior of SPW on cantaloupe plants were leaf structure, gravity, and light.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: March 1992 to present.

ANATOMY OF *BEMISIA TABACI*

The accessory salivary glands of *Bemisia tabaci* are spherical, 40μ structures composed of 4 or 5 cells which, together, form a cuticle-lined, microvillar lumen in the center. The cells are nucleate but, unlike the primary salivary glands, do not contain protein synthesizing organelles. Their ducts, and those of the primaries, travel directly into the beak independently of the alimentary canal.

The vector's midgut extends from the base to the apex of the abdomen, then loops back to the base again. Anterior and posterior aspects are fused together for several cell lengths in this area. Their respective basal lamina are breached at this point such that the basal membrane of the cells of the anterior aspect are in direct contact with those of the posterior aspect across an isthmus. The cells on the anterior side of the isthmus are the brush border cells that line the continuous lumen of the midgut. Those on the posterior side, however, are a specialized group that form a filter chamber. The brush border cells continue over it, then attenuate in transition to the hindgut. The tract enters into a sharp convolution at this transition. The filter chamber extends in a posterior direction from the isthmus into the continuous lumen for about ¾ the length of the convolution as a sac-like lobe. It consists of two epithelial layers which have lumina of their own. One is made up of brush border cells also, and probably functions as a malpighian tubule, however, to the extent that serial reconstruction can determine, its lumen is apparently closed to the continuous lumen at both ends. The other layer is oesophageal. After passing through the petiole, the oesophagus penetrates into the convolution, then runs in a posterior direction, adjacent to and in adherence with, the first layer. The lumen of the oesophagus appears to be closed also.

There is no question that the whitefly digestive system is an organ of disease transmission. Symptomology suggests that virions are somehow concentrated in the body. Inferences can now be made on how nourishment travels through the digestive system, how water balance is regulated, and in which tissues viral particles might accumulate passively. All organs of digestion are now recognizable in immunoready specimens. We have achieved high specificity labelling with sera and DNA probes on infected plant tissue, and are trying to localize these labels in undissected tissue.

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RESEARCH & IMPLEMENTATION AREA: Section B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: Research conducted from 1992-1993.

THE KINETICS AND INHIBITION OF WHITEFLY (*BEMISIA TABACI*) ACETYLCHOLINESTERASES AND HOST PLANT INFLUENCES ON THE KINETIC PARAMETERS OF ACETYLCHOLINESTERASE ACTIVITY IN THE 'A' AND 'B' BIOTYPES.

The basic kinetic parameters, K_m and Vmax were defined for the enzyme, acetylcholinesterase, in *Bemisia tabaci*. The inhibitors used to qualitatively assess enzyme activity were paraoxon, propoxur, profenofos, and permethrin. These compounds were chosen because they are representative of the major classes of insecticides used to control the whitefly.

All assays were done spectrophotometrically with the Ellman protocol. Baseline acetylcholinesterase activity was established with a minimum of four substrate concentrations. Each inhibitor was tested at two dose levels against a minimum of three substrate concentrations, and with a minimum of three replications/dose/substrate amount.

To determine if the host upon which the whiteflies were reared affects the ability of the insects to respond to the application of an insecticide, whitefly colonies were reared on a variety of host plants. host varieties included beans and cotton for the 'A' biotype, and beans, broccoli, poinsettia, and cotton for the 'B' biotype. All the whitefly colonies were begun from the same laboratory colonies of the 'A' and 'B' biotypes maintained on cotton at the University of Arizona. All of the whitefly colonies were allowed to live and reproduce for a minimum of three months on their new host plants in a greenhouse prior to assays. Greenhouses were maintained with natural lighting and a temperature regime of 15° C to 35° C.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research-Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Virus Vector Interactions

DATES COVERED BY REPORT: May - November 1993

ASSESSMENT OF SEX RATIOS IN THE 'A' AND 'B' BIOTYPES OF *BEMISIA TABACI* GENN.

Cage studies were undertaken throughout the summer and fall of 1993 to study the population ecology of the whitefly, *Bemisia tabaci*. Each of the following three combinations of whiteflies were replicated with three cages each, in both the field and greenhouse:

(1) 25 mating pairs of the 'A' biotype with 25 mating pairs of the 'B' biotype;
(2) 50 mating pairs of only the 'A' biotype;
(3) 50 mating pairs of only the 'B' biotype.

Cotton was used as the host plant for the rearing of the whiteflies in all of the cages. The ambient temperatures and lighting conditions were used for the field cages, while the natural photoperiod and a temperature range of 35° C (max) to 15° C (min) was maintained in the greenhouses.

Weekly samples of adult insects were obtained from all of the cages. These samples were used to establish a sex ratio for both biotypes. Additionally, individual female whiteflies were analyzed weekly with native PAGE to search for any unusual esterase banding patterns in the whitefly progeny from the cages which contained both biotypes.

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RESEARCH & IMPLEMENTATION AREA: Section B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: Research conducted from 1991-1993.

BIOTYPES OF *BEMISIA TABACI* IN EURASIA AND THE DETECTION OF THE 'B' BIOTYPED IN THE MEDITERRANEAN BASIN BY ESTERASE PROFILE ANALYSIS

Bemisia tabaci adults were collected from many habitat types under a diverse range of climatic and geographic conditions throughout Eurasia and the Indian subcontinent from 1991 to 1993. Attempts were made to match these habitat types to a variety of areas in the U.S. where this insect is a severe agricultural pest. Esterase profiles of the whiteflies were determined with native PAGE gels, and used for the preliminary separation of the whitefiles into biotypes.

This survey provides valuable information on the biotypes of a number of B. *tabaci* populations across Eurasia. The results of the electrophoretic analyses reveal multiple biotypes of this whitefly exist. Some esterase profiles are characteristic of whitefiles from specific host plants and/or geographic locations. But other esterases, which are also present in the profiles, appear to be independent of either host plant or locale, and appear in several of the samples assayed.

The new form of *Bemisia*, termed the 'B' biotype, was found to occur in Pakistan, Egypt, and Spain. The detection of this new strain of *Bemisia* in these countries indicate this whitefly is now found in the Mediterranean Basin, and appears to be dispersing eastward into Asia.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: 1992 December 1993.

USE OF GENETIC FINGERPRINTING FOR IDENTIFICATION OF WHITEFLY PARASITOIDS

A large number of parasitoids in the genera *Eretmocerus* and *Encarsia* (Hymenoptera: Aphelinidae) are currently being utilized and extensively studied for biological control of the sweetpotato whitefly, *Bemisia tabaci*. Research with these minute wasps has been hampered by difficulty in their identification. Random amplification of polymorphic DNA (RAPD) using the polymerase chain reaction (PCR) has been successfully utilized in taxonomic studies of many organisms, including the parasitic hymenoptera; live and dried individuals can be identified.

We have demonstrated that RAPD-PCR is a fast and reliable technique for the identification of several aphelinid parasitoids of *B. tabaci*. Specimens examined so far include *Eretmocerus* nr. *californicus*, *Encarsia formosa* and *En. luteola*, collected in various sites throughout Arizona and California, and *Er. mundus* from Spain. Each of these four species yields a distinctive pattern with several primers tested. The results have been consistent and reproducible under different experimenters and using various thermal cyclers for the PCR reaction. At least one primer yields a consistent pattern across populations within each species. The tested *Encarsia* specimens were previously identified by Dr. A. Polaszek (Natural History Museum, London).

Some researchers have successfully used RAPD-PCR to distinguish 'strains' or 'biotypes' within a species. We are currently attempting to distinguish differences between three *Encarsia formosa* strains. The seven primers tested so far yield similar banding patterns for the *En. formosa* collected in Egypt and Arizona, and reared commercially.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: 1992-1993

WHITEFLY ENDOSYMBIONTS

Immature whiteflies contain paired oval mycetomes composed of large cells (mycetocytes) hypothesized to contain symbiotic microorganisms. Treatment of *B. tabaci* B biotype females with an antibiotic (oxytetracycline hydrochloride) delivered through root treatments of host plants adversely affected adult oviposition, growth and development of offspring, and reduced mycetome size. These results suggest that microorganisms in the mycetomes of whiteflies are symbiotic in nature, as reported in other homopterans, and required for proper growth and development. Treatment of adult females with the antibiotic reduced the ability of immatures to induce symptoms of squash silverleaf, however, it is not clear if the reduction in squash silverleaf was due to the smaller size of treated offspring, reduced feeding by treated offspring, or to the damage done to the endosymbionts.

The ultrastructure of the mycetocytes and mycetomes micro-organisms was observed using transmission electron microscopy. In *B. tabaci* B biotype, two morphologically distinct types of micro-organisms were observed in mycetocytes. The predominant type lacked a distinct cell wall, was pleomorphic in shape with a surrounding vacuole. The second type was a coccoid organism, with inner and outer cell membranes typical of gram negative bacteria. In the greenhouse whitefly, *Trialurodes vaporariorum*, pleomorphic and coccoid organisms were also found, although the coccoid microorganism in the greenhouse whitefly had a thicker cell wall than the coccoid organism in *B. tabaci*.

Publications:

H. S. Costa, D. E. Ullman, M. W. Johnson & B. E. Tabashnik. 1993. Antibiotic exytetracycline interferes with *Bemisia tabaci* (Homoptera: Aleyrodidae) oviposition, deelopment, and ability to induce squash silverleaf. Ann. Entomol. Soc. Am. 86: 740-748.

H. S. Costa, D. M. Westcot, D. E. Ullman & M. W. Johnson. 1993. Ultrastructure of the endosymbionts of the whitefly, *Bemisia tabaci* and *Trialeurodes vaporariorum*. Protoplasma 176: 106-115.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research-Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Virus Vector Interactions

DATES COVERED BY REPORT: October 1991 - February 1993

THE EFFECTS OF WHITEFLY POPULATION CHANGES ON LETTUCE INFECTIOUS YELLOWS VIRUS EPIDEMIOLOGY

Lettuce infectious yellows virus (LIYV) has been a limiting factor in the production of crops in the desert regions of southwestern USA since 1981. The virus, which is vectored by the sweetpotato whitefly, attacks at least 10 major agricultural crops including lettuce, cantaloupe, cucumber, melons, squash, watermelons, sugarbeet, and carrots. The economic impact of LIYV infections in crops grown in the southwest desert regions was devastating. Lettuce, sugarbeet and melon plantings during the 1980's were virtually 100% infected. Yield losses in lettuce were in the range of 50-70%. Losses of sugarbeets have been estimated at 20-30%, or approximately $9 million per year. The losses in cucurbits were in the range of 20-50%. In addition to these losses, the limited availability of produce, especially lettuce, during the late fall and winter periods boosted consumer prices in some instances over 600%, causing great losses to consumers.

Following the introduction of biotype "B" into the southwest desert whitefly population in 1990 and the establishment of its gene pool into the resident population, a number of important changes in LIYV epidemiology took place. The new biotype and hybrid populations developed much higher population levels than the "A" biotype. The new populations were much poorer vectors of LIYV (almost 100 fold less efficient). The new population developed more rapidly and were so destructive to melons that virtually no fall melons were planted in 1992. Thus, in spite of record whitefly populations, the absence of the major source of the LIYV (fall melons) resulted in very low incidence of virus in 1991 and 1992 fall crops (less than 0.1%). The virus was still present in the region but was not of economic significance, and record lettuce and sugarbeet yields have resulted.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research-Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Virus Vector Interactions

DATES COVERED BY REPORT: October 1, 1992 - September 30, 1993

PARTIAL CHARACTERIZATION OF A NEW CLOSTEROVIRUS, THE CAUSAL AGENT OF CUCURBIT YELLOW STUNTING DISORDER

Whitefly-transmitted yellowing viruses of cucurbits are causing severe economic losses throughout the world. In western USA lettuce infectious yellows (LIYV), vectored by *Bemisia tabaci*, caused large losses to cucurbits, lettuce and sugarbeet. In the USA, Europe, Asia and the Mediterranean region beet pseudo yellows virus (BPYV), vectored by *Trialeurodes vaporariorum*, causes major losses in controlled environments and outdoors in warmer regions. In the early 1980's a yellowing and stunting disorder of cucurbits was noticed in the middle east. On the basis of observations and limited serological studies this disease appeared to be distinct from LIYV and BPYV.

This virus, herein named Cucurbit yellow stunting disorder virus (CYSDV), is transmitted by the sweetpotato whitefly (*Bemisia tabaci*) in a semipersistent manner. The virus appears to have a narrow host range, mainly in the Cucurbitaceae. The virus can cause economically significant losses on melons and cucumbers. The virus has been purified by differential centrifugation. Purified preparations contained long, flexuous particles 12 x 1200 nm. The host range, insect transmission and serology clearly distinguish CYSDV from previously described viruses.

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RESEARCH & IMPLEMENTATION AREA: Section B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: April 1993 through December 1993

DEVELOPMENT OF MOLECULAR MARKERS TO FACILITATE POPULATION CHARACTERIZATION OF THE WHITEFLY, *BEMISIA TABACI*

The sweetpotato whitefly, *Bemisia tabaci* has been shown to consist of several biotypes based on general esterase staining patterns, and such biological parameters as host plant affinity, and the ability to transmit any number of a suite of geminiviruses. In order to more thoroughly characterize populations and/or explore the possible relatedness of the various biotypes, we are using DNA markers from both the nuclear and mitochondrial genomes to examine representatives of populations from five continents. The markers employed are based both on RAPD (random amplified polymorphic DNA) patterns from the nuclear genome and direct sequence data from the mitochondrial genome. Relationships are being assessed with parsimony, distance, and maximum likelihood methods.

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RESEARCH & IMPLEMENTATION AREA: Section B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: 1993

DNA VARIATION AMONG POPULATIONS OF *BEMISIA TABACI* GENNADIUS (HOMOPTERA: ALEYRODIDAE)

The B biotype of *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae), the sweetpotato whitefly, has become a significant economic threat to agriculture. Variability in a number of morphological and biological factors has led to questions about the genetic relationships between *B. tabaci* populations. We used RAPD-PCR to examine DNA variation among 15 populations of *B. tabaci* collected around the world, and one population of greenhouse whitefly (*Trialeurodes vaporariorum*). Insects could be grouped according to similarity in RAPD band patterns; insects from the 15 *B. tabaci* populations could be reliably classified as belonging to one of 4 groups. The *T. vapararioum* population was always distinct from the *B. tabaci* populations. No consistent host-associated classification was found. Our results indicate that variation between the A and B biotypes is somewhat continuous, but also documents discrete, non-continuous variation between other populations. Viewed as a world-wide organism, *B. tabaci* appears to be a variable collection of heterogeneous subunits (populations) rather than a single homogenous collection of genotypes. Discussions of taxonomic relationships among *B. tabaci* populations may need to address the apparent genetic plasticity of this organism.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: November 1992 - December 1993

SWEETPOTATO WHITEFLY HONEYDEW ANALYSIS AND ENZYME DEGRADATION

Cotton lint contaminated with sweetpotato whitefly (SPWF) honeydew is very difficult to process, causing severe problems in ginning, spinning and weaving. Because of this fact, cotton so contaminated commands a significantly lowered price. This problem is found in most cotton-growing countries, and in the United States it is most severe in the irrigated southwest. A collaborative project is underway to determine the chemical nature of the sugar components in this secretion and, using this information, to design ameliorative measures utilizing carbohydrate-degrading enzymes. Laboratory investigations have shown that when the SPWF feeds upon cotton phloem it rapidly converts sucrose, the single sugar in this sap, into at least thirty saccharides. Some of the sugars in this exudate have highly unusual structures. A number of them, including most of the larger sugars, contain the trehalose [i.e., α-G-glc-(1$\leftrightarrow$1)α-D-glc] moiety. A number of enzyme preparations have been tested against this mixture and several have been found which are capable of degrading these saccharides with concomitant diminution in the stickiness of contaminated lint as determined by either the thermodetector or minicard devices.

Field tests were conducted in which sticky cotton was sprayed at harvest with enzymes in aqueous solution by employing spraying equipment on a commercial cotton picker. Samples of treated and untreated seedcotton were held in the laboratory in sealed containers for various lengths of time, following which the lint was removed and tested for stickiness and sugar content by HPLC. Water content of the fiber was also determined by weighing wet and oven dried samples.

The enzymes tested were found to significantly reduce the stickiness of SPWF honeydew-contaminated cotton fiber. Adding water alone to cotton lint also diminishes stickiness through its activation of the microbial flora on the fibers; however, the enzymes removed the stickiness more quickly and completely than water alone. In addition, analysis of the residual sugars indicated that when the enzymes reduced stickiness they did not remove all the sugars on the lint, only certain components. This is due to the fact that sugars differ in their effective stickiness (W. B. Miller et al., *in press*).

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DATES COVERED BY REPORT: 1993

SILVERLEAF WHITEFLY-INDUCED TOMATO IRREGULAR RIPENING

Silverleaf whitefly induces squash silverleaf and irregular ripening in tomatos. In each of these conditions it is clear that the normal development and differentiation of plastids has been affected markedly. The underlying mechanism(s) involved in these disorders is unknown; however, transmission and grafting studies have ruled out the possibility of a pathogenic process. This, along with the positive correlation of symptom severity with numbers of feeding insects, the translocatability and gradation of systemic symptoms when insects are restricted to specific portions of host plants and the reversibility of these effects within new tissues when feeding insects are removed, implicate a soluble salivary component as the causative factor. Feeding on tomato foliage completely suppresses the ripening response in sectors of otherwise normal tomato fruit. Since this failure to ripen is not responsive to treatment with ethylene, receptors for this plant hormone may be involved. Other ethylene-responsive genes, such as those associated with insect defense responses, also may be affected. We are using the silverleaf whitefly-tomato irregular ripening phenomenon to gain insights into normal developmental events involved in tomato fruit ripening and the mechanism(s) by which irregular ripening is induced by the insect. Because fruit from whitefly-infested plants cannot be stimulated to ripen by exogenous ethylene treatment, unlike other systems investigating fruit ripening, study of this system will allow us to characterize signal transduction pathways that precede the impact of ethylene, both in ripening, and defense and wounding responses.

We have succeeded in producing irregular ripening symptoms in experiments conducted in insect exclusion cages. Throughout the experiment, whitefly densities were monitored. Similar to earlier findings we observed a positive relationship between whitefly densities and the degree of symptom development.

To assess symptom severity, flowers were tagged weekly after insect infestation and fruit were allowed to develop. During the course of the eight-week experiment, 40 newly fertilized flowers were tagged per treatment each week. Forty-five days after tagging, fruit were in the mature green stage and 12 fruit were harvested from each treatment along with leaf tissue. A subset of four of these fruit were assessed at the time of harvesting. The remaining two subsets of four fruit each were allowed to ripen at 20°C with an alternating light/dark regime of 16/8 h for 7 and 14 days, respectively. After transverse transection, fruit were scored on the basis of the overall appearance of the external surface and the internal cut surface. A rating of "normal" was given to fruit which appeared unaffected. Fruit rated as "slight" were those in which incomplete reddening of the surface was accompanied by the presence of white internal tissue. Those in which irregular ripening was "marked" had extensive areas of the surface of the fruit which were green accompanied by extensive white or green internal tissue. A photographic record was made of all fruit from each stage of ripening for each harvest from each treatment. The cut surface of one half of each fruit was blotted onto Hybond N membranes, and the membranes fixed and stored under vacuum at room temperature. The locule contents were separated from the pericarp and these tissues and leaves were frozen in liquid nitrogen and stored at -80°C. Tissue print and RNA blot hybridizations using previously characterized ripening, photosynthesis, wounding, and defense-related gene clones are being conducted with fruit and leaf samples from this experiment.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATE COVERED BY REPORT: 1993 Field Season.

EPIDEMIOLOGY AND ETIOLOGY OF BGMV IN SOUTH FLORIDA

An epidemic of bean golden mosaic virus (BGMV) was observed in the spring of 1993 in south Florida. The disease was found in snap beans, *Phaseolus vulgaris* L. and *P. limensis* Macf. in S. W. Dade County and S. E. Palm Beach county. Plants with bright golden mosaic symptoms from the diseased fields tested positive for geminivirus with a replicated dot blot hybridization assay. These samples did not react with specific DNA-B probes from tomato mottle virus (TMOV) and *Macroptilium lathyroides* geminivirus previously described from Florida. An isolate of the virus from Homestead, FL (BGMV-HO) was mechanically transmissible to *P. vulgaris* cv. Topcrop. The sweetpotato whitefly, *Bemisia tabaci*, was an efficient vector of the disease in transmission tests. The nucleotide sequence of the intergenic region of DNA-B of BGMV-HO was highly homologous with type II BGMV from the caribbean. The affect of Bean golden mosaic on snapbeans, disease incidence and alternate host for BGMV were studied and will be discussed.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: January 1992 to May 1993

USE OF THE POLYMERASE CHAIN REACTION TO DETECT VIRULIFEROUS INDIVIDUALS OF *B. TABACI* (HOMOPTERA: ALEYRODIDAE) WITH TWO TOMATO-INFECTING GEMINIVIRUSES.

The sweetpotato whitefly, *Bemisia tabaci* (Genn.), is an economically important pest worldwide. A new strain of sweetpotato whitefly, the "poinsettia strain" causes extensive damage by direct feeding and by the transmission of plant viruses, such as geminiviruses. In the Mediterranean, tomato yellow leaf curl geminivirus (TYLCV) is the most serious disease in tomatoes. Another whitefly-transmitted geminivirus, tomato mottle geminivirus (ToMoV), is presently a serious problem in tomato production in the southern United States. Because of the increasing importance of whitefly-transmitted geminiviruses, it is necessary to develop rapid and simple diagnostic methods for the detection of viruliferous whiteflies.

The polymerase chain reaction (PCR) is an extremely sensitive and specific technique for the detection and identification of plant pathogens. PCR methods were successfully used to amplify 1.1-kb DNA fragments from individual viruliferous *B.tabaci* carrying either TYLCV or ToMoV, and no amplified DNA fragments were obtained when non-viruliferous *B.tabaci* adults were similarly processed. Southern hybridization analysis proved that fragments amplified from viruliferous *B.tabaci* adults were viral DNA. This PCR-based detection method is sensitive enough to detect TYLCV and ToMoV in individual viruliferous *B. tabaci* in mixed samples of up to 25 (1 viruliferous: 24 non-viruliferous) and 10 (1 viruliferous: 9 non-viruliferous) individuals, respectively. The potential uses of this PCR-based detection method in epidemiological studies of geminiviruses are discussed.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: January 1993 - December 1993

STICKINESS OF INDIVIDUAL WHITEFLY HONEYDEW CARBOHYDRATES ON COTTON LINT

Trehalulose, (1-O-α-D-glucopyranosyl-D-fructose), was identified in 1990-1992 as the single largest sugar component in *Bemisia tabaci* honeydew when this insect feeds on sucrose translocating plants, including cotton (1, 2, 3). This and other (4) work has led to comprehensive characterization of sugars present in *Bemisia* honeydews, which includes trehalulose, sucrose, raffinose, reducing sugars, melezitose, and a series of higher-order oligosaccharides based on trehalose.

Although lint stickiness due to insect honeydew contamination is a long-standing problem with arid region cottons, much remains to be discovered about the mechanism of lint stickiness. We undertook a series of studies to determine the level of stickiness individual carbohydrate components impart to cotton lint. Such information is valuable in guiding pre- or postharvest intervention efforts aimed at ridding sticky components from lint.

Using a thin layer chromatography sprayer, we applied a series of standard sugar solutions onto clean Acala-90 cotton lint. Typically, 1.0 ml of distilled water (containing 0-100 mg carbohydrate) and a 0.2 ml sprayer rinse were sprayed onto 10 g batches of cotton which had been uniformly spread to ca. 620 cm2. Electron microscopy revealed similar size and appearance of dried sugar droplets with authentic honeydew spots. After air drying overnight, stickiness was rated on a minicard apparatus, a universally accepted method for determining lint stickiness.

We found that trehalulose and sucrose were, by far, the stickiest sugar components of *Bemisia tabaci* honeydew. At 0.08-0.1% (w/w), these sugars gave a minicard rating of 3 (the stickiest rating possible). Turanose was slightly less sticky, with 0.1-0.12% being required for a rating of 3. Melezitose, glucose, and fructose were all essentially non-sticky, with levels up to 1.0% giving minicard ratings less than 2. An "artificial honeydew" prepared with all available honeydew sugars (45% trehalulose, 15% sucrose, 15% glucose, 10% fructose, 10% melezitose and 5% turanose) was essentially as sticky as trehalulose and sucrose, yielding a minicard value of 2.5 at 0.1% (w/w). An hypothesis that longer chain oligosaccharides would be stickier than shorter sugars was rejected by the fact that sucrose and trehalulose (disaccharides) were stickier than melezitose, raffinose, stachyose, and inulin (tri, tetra- and long chain oligosaccharides).

1. Carbohydr. Res. (Amsterdam) 201:342-345, 1990.
2. J. Insect Physiol. 36:433-439, 1990.
3. Comp. Biochem. Physiol. 101B(1/2):23-27, 1992.
4. Plant Physiol. 98:753-756, 1992.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: January to December, 1993.

ULTRASTRUCTURAL ON THE NYMPHAL CUTICLE AND THE EGG MEMBRANES OF *BEMISIA TABACI* AND *TRIALEURODES VAPORARIORUM*

Ultrastructural studies were made on the nymphal cuticles and the egg membranes of *Bemisia tabaci* and *Trialeurodes vaporariorum*. During the cuticle work transverse sections of each instar were examined. Points of emphasis included (a) general features of the cuticle and epidermal cells at different stages of each instar, and (b) specializations of the cuticle and epidermal cells in relation to such things as the wax filled breathing grooves leading to the spiracles (always ventral and next to the leaf surface during the immature stages), wax spines, and the palisade found around *T. vaporariorum* pupae.

Overall, the cuticles of both species were similar and fairly typical of the cuticles of a wide range of insects. A thin epicuticle ($< 1\mu$) could usually be detected. Below the epicuticle there was an exocuticle, a laminated endocuticle and typically a subcuticle. The cuticle over most of the nymph was of moderate thickness, but ventrally, in the areas in contact with the host leaf, the cuticle was very thin, with an endocuticle that was poorly defined in many specimens that had well defined endocuticles dorsally. No morphological features were found in the epidermal cells that could be correlated with formation of wax spines or the small wax plates of the breathing grooves. However, laterally there was more morphological evidence of specialized wax secretion by the epidermal cells. This was particularly true in pupae of *T. vaporariorum*; cells adjacent to the external wax plates called the palisade had prominent clusters of tubular smooth endoplasmic reticulum (SEM) not seen elsewhere in the epidermal cells. It appeared probable that the SER was involved in synthesis of the palisade wax.

Egg stalks were found to have walls with thick multiple layers of fibrous material. The lumen contained an array of dense strands that presumably represented a precipitate formed at fixation. Cytoplasm or yolk was never seen in the egg stalk. Mycetomes with their enclosed symbionts formed a prominent mass at the distal end of each egg as in aphids and other homopterans. The mycetomes appeared as a "plug" separating the lumen of the egg from that of the proximal end of the egg stalk.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Vector Interactions.

DATES COVERED BY REPORT: January 1993 through December 1993

GEMINIVIRUS ACQUISITION/TRANSMISSION BY *BEMISIA TABACI*

B. tabaci is the only whitefly species capable of vectoring geminiviruses. As with many Homopteran insects, feeding is accomplished with stylets which enter the sieve tubes of the phloem. We have investigated the morphology of the mouthparts of the whitefly by light microscopy (LM) and scanning (SEM) and transmission electron microscopy (TEM). We have shown that the stylet arrangement in the whitefly is similar to that of aphids and thrips, which are also insect vectors of plant viruses. Four stylets make up the piercing-sucking organ and are adapted to first penetrate plant tissue and then to extract sap. There are two outer mandibular and two inner maxillary stylets. On the outer surface of the two mandibular stylets, there is a series of more or less concentric, curved and barb-like ridges that extend over the most distal 40 μm of the stylets. The mandibular stylets each contain a central duct that is ovoid, slightly off-center and contains two dendrites. At the distal tip, the maxillary stylets are sharply pointed, have grooved edges and have a spoon-shaped central depression. The maxillary stylets are interlocked by a series of ridges and grooves to form two separate compartments, the food canal and the smaller salivary canal. The salivary canal is contained almost entirely within one stylet and the food canal is centrally located, formed equally by the apposition of the food grooves in both stylets. The food canal is larger (0.65 μm in width) than the salivary canal (0.215 μm in width). Both the canals end short of the stylet tip and terminate in the spoon-shaped depression.

We are using the situ nucleic acid hybridization at the light microscopy level to localize squash leaf curl geminivirus (SLCV) particles in the adult whitefly. Preliminary data indicate localization of virions in the accessory salivary glands, hindgut and hemocoel. We are presently optimizing experimental conditions with regard to DNA hybridization conditions, TEM embedding media and other parameters for the electron microscope level which will enable subcellular localization of virions.

In order to identify viral coat protein epitopes involved in geminivirus/whitefly interactions, we have accessed the GenBank/EMBL databases for nucleotide sequences of whitefly-transmitted (WFT) geminiviruses and are using the GCG (Wisconsin) sequence analysis software to search for nucleotide and amino acid sequence similarities between different geminivirus coat proteins. Multiple sequence alignment of coat protein deduced amino acid sequences from WFT monopartite and bipartite geminiviruses indicate 82% similarity (76% identity) and delineate several conserved regions having identical amino acids that are shared between the two whitefly-transmitted virus subgroups. These regions will be compared to other ligand-receptor-like proteins for sequence similarity in order to identify geminivirus capsid epitopes involved in geminivirus/whitefly interactions.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Vector Interactions.

DATES COVERED BY REPORT: November 1992 to December 1993.

COMPARISON OF SWEETPOTATO WHITEFLY (BEMISIA TABACI)-INDUCED SILVERLEAF WITH PLANT GROWTH REGULATOR-INDUCED LEAF SILVERING

B-biotype sweetpotato whiteflies (*Bemisia tabaci*) induce several disorders of cucurbits, including squash silverleaf (SSL). Larval whiteflies seem to be solely responsible for induction of SSL. Specific host plant responses appear in concert with squash silverleaf, including autolysis of mesophyll cells at the feeding site, decreased root mass and chlorophyll content, altered intercellular protein profiles, and the stunted development of leaf columnar parenchymal cells that is responsible for upper leaf-surface silvering. Specific intercellular proteins in silverleaf-affected leaves were dramatically induced or suppressed by B-biotype whiteflies and not by A-biotype whiteflies or by plant growth regulators (PGRs) such as Cycocel and Paclobutrazol. In parallel with appearance of silverleaf in sweet sugar pumpkin, proteins of 31,000 and 70,000 molecular weight were induced by SPW-B feeding, and a 60,000 molecular weight protein was suppressed, as determined by SDS-polyacrylamide gel electrophoresis (PAGE). Using 2-dimensional PAGE, at least eight induced proteins were visible at 4 different molecular weights. At least 6 other proteins at 3 different molecular weights appeared to be suppressed by SPW-B infestation. The specific induction or suppression of intercellular proteins by B-biotype whiteflies may be useful in regulating innate or engineered host plant defenses for management of SPW populations.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions.

DATES COVERED BY REPORT: November 1992 - March 1993.

OVIPOSITIONAL RESPONSE TO LEAF SURFACES

Ovipositional leaf surface preference of *Bemisia tabaci*, was studied under laboratory conditions on early vegetative growth of commercial cultivars of ten vegetable crops: cantaloupe, cucumber, eggplant, bell pepper, collard, southernpea, snap bean, summer squash, tomato, and watermelon. In a choice test using detached leaves with both surfaces turned downward, the lower leaf surface of cantaloupe, squash, and watermelon, was preferred for oviposition as compared with the upper surface. However, the upper surface was preferred in southernpea. Oviposition was similar between leaf surfaces on the six other vegetables.

Four crops, cantaloupe, cowpea, snap bean, and squash, were evaluated for whitefly geotropic response for oviposition; there was a strong negative response. Results from the previous summer, 1992, indicate that 90 to 95% of the eggs and nymphs occurred on the bottom surface of these 10 crops in field and greenhouse tests. Collard and southern pea lacked pubescence on either surface while the amount of pubescence varied between surfaces on the other crops. Although pubescence may partly explain the preference for the lower leaf surface, other factors, e.g. geotropism, are apparently more important.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: 1993

MORPHOLOGICAL AND PHYSIOLOGICAL PARAMETERS ASSOCIATED WITH SWEETPOTATO WHITEFLY HOST SELECTION

To understand sweetpotato whitefly host selection we examined the effects of phosphorus nutrition and leaf age on oviposition. Plant physiological parameters included leaf soluble sugar (glucose, fructose, and sucrose) concentration, free amino acid concentration, water potential, transpiration rate, and abaxial surface temperature. Oviposition was greatest on the youngest leaf, then decreased with each older leaf. Of all parameters examined, leaf position was most consistently correlated with the number of eggs cm^2. Phosphorus deficiency reduced oviposition in 5 of 6 experiments by an average of 20%. Host selection was negatively correlated with sucrose concentration but was not affected by leaf amino acid concentration. It appears that leaves were selected based on their potential to minimize osmotic stress to the insect rather than on their ability to provide a high amino acid diet.

Phosphorus deficiency induced leaf water stress symptoms, as indicated by low leaf water potential and reduced transpiration rate. Within nutrient treatments, low leaf water potential was associated with increased oviposition, similar to reported effects of drought stress on host selection. High phosphorus plants, however, had higher leaf water potential than low phosphorus plants. This suggests that phosphorus effects on oviposition were due to factors other than their effect on leaf water status.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

REPORTING PERIOD: September 1992 - September 1993

DETERMINATION OF TEMPORAL ACTIVITY AND DIRECTIONAL INFESTATION GRADIENTS OF SILVERLEAF WHITEFLY, *BEMISIA ARGENTIFOLII*

Yellow sticky cards were monitored at hourly intervals on four dates in October 1992 and six dates (June-August) in 1993 to determine diurnal flight activity of silverleaf whitefly (SLW) with respect to meteorological conditions. In absence of wind, SLW flight activity peaked in mid-morning, with a minor secondary peak at sundown; windy conditions generally resulted in absence or delay of a definable peak of flight activity.

Grid-wise sampling of a cotton field for SLW immatures demonstrated a pronounced early directional gradient in infestation density which persisted until crop termination. Density was highest along the east and south field margins; coincidentally, SLW movement during the morning peak of flight activity also tended from southeast to northwest.

INVESTIGATOR'S NAME(S): Prem Mehta[1], Jeffrey A. Wyman[1], M. K. Nakhla[2], Douglas P. Maxwell[2].

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: July 1992 to July 1993

TRANSMISSION STUDIES OF TOMATO YELLOW LEAF CURL GEMINIVIRUS BY THE VECTOR *B. TABACI* (HOMOPTERA: ALEYRODIDAE).

The sweetpotato whitefly, *Bemisia tabaci* (Genn.), is an economically important pest worldwide. A new strain of sweetpotato whitefly, the "poinsettia strain" causes extensive damage by direct feeding and by the transmission of plant viruses, such as geminiviruses. In the Mediterranean, tomato yellow leaf curl virus (TYLCV) is a serious disease in tomatoes causing losses of up to 95% in Egypt. Because of the increasing importance of whitefly-transmitted geminiviruses, studies were conducted to quantify the characteristics of TYLCV transmission by the vector *B. tabaci*. Such studies will be essential in future investigations of viral epidemiology and in the development of effective management strategies. In this paper the transmission characteristics, and virus-vector relationships of TYLCV, a whitefly-transmitted geminivirus from Egypt are described.

Transmission of TYLCV was achieved with single *B. tabaci* adults but the efficiency of transmission increased 4-fold as *B. tabaci* numbers were increased to 5 per plant. *B. tabaci* transmitted TYLCV after a minimum acquisition-access period (AAP) of 15 min. The rate of transmission increased as the AAP was lengthened and reached a maximum after 24 h AAP. A minimum inoculation-access period (IAP) of 15 min was observed with the rate of transmission increasing as the IAP was lengthened, reaching a maximum after 12 h IAP. The transmission data was confirmed directly in both test plants and in individual vectors by detection of TYLCV nucleic acids in squash blots.

When *B. tabaci* were serially transferred after acquisition, adults were unable to transmit TYLCV until 24 h after the initiation of the AAP regardless of the length of acquisition provided. The 24 h transmission threshold from initial vector access to a TYLCV source plant until transmission of the virus included both the AAP, which can be as short as 15 min, and the latent period during which the virus may circulate or multiply within the vector. Retention of TYLCV from the nymphal to adult stages of *B. tabaci* was supportive of a circulative mode of transmission.

TYLCV titer in *B. tabaci* after an AAP of 12 h (measured as radio activity of squashed vectors by Betascope blot analyzer) continuously increased on non-TYLCV hosts starting at 12 h, reaching a peak at 108 h and remaining stable from 132 h to 180 h after AAP. Our data suggests multiplication of TYLCV in the vector *B. tabaci* as the most likely explanation for the continuous increase of TYLCV titer and from these studies, transmission of TYLCV by *B. tabaci* is most accurately described as circulative, propagative.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, biochemistry, biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: 1993

FEEDING AND OVIPOSITION BEHAVIOR OF WHITEFLIES

Electronic waveforms produced by feeding and oviposition activities of two whitefly species, *Parabemisia myricae* (Kuwana) and *Bemisia argentifolii* Bellows & Perring, generally were similar but had some subtle differences. Stylet penetration almost always started with a sawtooth waveform (repetitious, large amplitude waves with a frequency ranging from 0.05 to 0.5 Hz) that was correlated (via styletectomy and light microscopy) with intercellular penetration by the stylets through the epidermis, mesophyll, and vascular tissue. Occasionally during stylet penetration, when whiteflies were producing sawtooth waves, stylet advancement stopped, the stylets were retracted slightly and then advanced into a new direction, leaving behind an empty salivary sheath. This was correlated with a sudden decrease in voltage level during the sawtooth waveform.

Ingestion from phloem sieve elements was correlated with a high-flat waveform (steady high voltage level with very little voltage fluctuation). Phloem ingestion always was preceded by 3 min of sawtooth waves followed by a brief transition wave that occurred between the sawtooth and high-flat waveforms. The transition wave is analogous to the aphid X-wave. *P. myricae* and *B. argentifolii* took an average of 24 and 16 min, respectively, from initiation of a penetration to phloem ingestion. A low-flat waveform (steady low voltage level with very little voltage fluctuation) was correlated with ingestion in some cases, but ingestion during this low-flat waveform probably was not from phloem sieve elements. The low-flat waveform may indicate more than one biological process.

Oviposition by both whitefly species produced a distinctive two-phase waveform; the first phase was correlated with penetration of the ovipositor into the leaf and the second phase was correlated with insertion of the egg pedicel into the leaf.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

REPORTING PERIOD: October 1992 - September 1993

OVIPOSITION PREFERENCE AND NYMPHAL PERFORMANCE OF TWO *BEMISIA* SPECIES

Comparative choice and no-choice studies were conducted under greenhouse conditions to evaluate the ovipositional preference of *Bemisia argentifolii* and *Bemisia tabaci*. In choice studies, both whitefly species laid the greatest proportion of eggs on zucchini, *Cucurbita pepo* L. The lowest proportion of eggs laid by *B. tabaci* was on cabbage, *Brassica oleracea* L., while *B. argentifolii* laid its lowest proportion on sugar beet, *Beta vulgaris* L. The proportion of eggs laid by *B. argentifolii* on cabbage was significantly greater than that laid by *B. tabaci*. In no-choice studies both whitefly species laid approximately the same number of eggs on zucchini; however, on cabbage and sugar beet, *B. argentifolii* females laid significantly more eggs. In bi-hourly counts, females of both whitefly species were found on each host in approximate proportion to their ovipositional preference.

Greenhouse studies were conducted to evaluate the influence of the aforementioned plants on *B. argentifolii* and *B. tabaci* nymphal survivorship and development. In general, percent survivorship for both whitefly species was the highest on zucchini and the lowest on sugar beet; cabbage yielded intermediate results. Moreover, *B. tabaci* nymphs did not survive beyond the first instar on sugar beet. Developmental time of both *Bemisia* species also was affected by the host plant. Mean total developmental time (egg to adult emergence) for *B. argentifolii* was comparable on cabbage (23.0 d) and zucchini (21.5 d); however, it was 11-12 d longer on sugar beet (34.3 d). *Bemisia tabaci* required ca. 14 days to develop on cabbage (30.0 d) than on zucchini (24.1 d). In addition, total developmental time for *B. tabaci* was significantly longer than *B. argentifolii* on both cabbage and zucchini. These results suggest that *B. tabaci* is more susceptible to differences in host plant suitability than *B. argentifolii*. In addition, females of both *Bemisia* species prefer to oviposit on plants that enhance nymphal survivorship and allow the shortest developmental time.

TABLE B. Summary of Research Progress for Section B - Fundamental Research - Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions in Relation to Years 1 and 2 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
B.1 Studies of feeding behavior: sensory receptors, ultra-structure, morphology, digestive physiology; intra- and interspecific competition.	Yr. 2: Continue studies from Year 1; characterize feeding by-products and digestive enzymes; determine influence of host plant morphology, physiology, ecology and phenology on SPW feeding behavior and competition.	X		Information on feeding, host preference, digestion, cuticular characterization and morphology is continuing to be gathered. There appears to be a correlation with the abundance of vascular bundles in leaf tissues of some crops and feeding preference of SPW; the greater the abundance the more likely SPW will feed. Vascular bundle location, i.e., proximity to the leaf surface, along with leaf structure, gravity, and light may contribute SPW underleaf habitat behavior. Microscopic examination of the digestive system indicates that it serves as an organ of disease transmission and inferences can be made concerning food movement within the system, how water balance is regulated and in which tissues viral particles may accumulate. Tests of carbohydrate components in SPW honeydew for stickiness in cotton lint indicate that trehalulose and sucrose were the stickiest components. Treatment of sticky cotton lint with enzymes at harvest removed the stickiness more quickly and efficiently than water treatments alone. Ultrastructural studies of the nymphal cuticles and egg membranes of SPW revealed typical cuticles in the nymphs. Egg stalks had walls of thick multiple layers of fibrous material; cytoplasm or yolk was not seen in the egg stalk. Feeding monitor studies were initiated.
B.2 Studies of biochemistry, physiology, nutrition, development and reproduction.	Yr. 2: Continue fundamental studies begun in Year 1; expand studies of genetic diversity; identify areas for continued emphasis.	X		SPW acetylcholinesterases were characterized kinetically with and without pesticides and studied to determine if plant hosts affected kinetic parameters. Identification of and occurrence of surface lipids and wax particles of SPW adults has been accomplished; there were no obvious differences in the composition of external lipids with respect to sex or host plant. Survivorship and development of SPW on zucchini, cabbage, and sugar beets was studied to determine host plant effects. Survivorship was best on zucchini and lowest on sugar beet. Development times were longer on cabbage (30 d) than on zucchini (23.1 d). Female SPW appear to prefer to oviposit on plants that enhance nymphal development.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
B.3 Studies to discover and analyze diagnostic characteristics of SPW, including component taxa, and to determine biological and genetic basis for development of biotypes, host races, and species, genetics and genetic diversity. Develop dsRNA and cDNA probe.	Yr. 2: Continue systematic analysis of SPW; provide molecular services based on information derived from Year 1.	X		The use of non-specific esterases to distinguish between the biotypes A and B, and the application of isozyme analyses to differentiate between genetically important loci were applied to monitoring the distribution of the A and B biotypes, as well as others, worldwide, and to further establish the substantial diversity that appears to oceur between *B. tabaci* populations. As a result, the B biotype has been proposed as a new species, *Bemisia argentifolia*. Morphological differences in one seta and a fold on the fourth instar pupal case further distinguish the A from the B biotype and constitutes partial credence for the proposed new species designation. RAPDs analyses of DNA from a collection of *B. tabaci* indicates genetic variability between populations and that RAPDs are not useful markers for assigning phylogenetic associations. Direct genetic analysis of ribosomal (nuclear) and mitochondrial DNA of the *B. tabaci* complex is underway.
B.4 Develop systematic analysis of the genus *Bemisia* utilizing various methods.	Yr. 2: Continue analyses of *Bemisia* species, defining characters using characters from morphological and DNA sequence studies; investigate value of supplementary methods (i.e., cuticular hydrocarbons, immunological assays, isozymes, symbiont associations, etc.)	X		Ultrastructural studies of whitefly eggs showed that mycetomes and their enclosed symbionts formed a prominent mass at the distal end of each egg as in aphids and other homopterans. The surface lipids and wax particles of *B. tabaci* (biotypes A & B) were characterized and no differences were found in the external lipids. The major wax esters were C46 and the major acid and alcohol moieties in the esters were C20 and C26, respectively. Major components of the wax particles were a C34 aldehyde and a C34 alcohol plus small amounts of C32 aldehyde and alcohol.
B.5 Identify and define SPW toxicogenic effects.	Yr. 2: Fractionate SPW and affected plants. Isolate toxicogenic fractions. Characterize endogenous mediators, Use cDNA probe to screen biotypes.	X		Feeding by biotype B larvae causes squash silverleaf which is in part the result of the plant responses including autolysis of mesophyll cells at the feeding site. Other responses to B biotype SPW feeding include the appearance of proteins at Mr 31,000 and 70,000 and the suppression of a Mr 60,000 protein in intercellular fluids of sweet sugar pumpkin. Other proteins that were suppressed were detected by 2-dimensional electrophoresis.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
B.6 Characterize SPW endosymbiote (SPWe) influence on metabolism, host range, and biotype formation.	Yr. 2: Develop methods for isolation and SPWe and extraction of nucleic acid. Amplify specific SPWe genes via PCR.	X		Mycetomes in immature ***B. tabaci*** contain microorganisms which appear to be symbiotic to whiteflies and necessary for survival. Antibiotic treatment reduced mycetome size in offspring produced from treated adults and also reduced the immatures' ability to induce phytotoxic SSL. Ultrastructural studies by TEM indicated at least two morphologically different types of microorganisms.
B.7 Investigate etiology of diseases; biological and molecular characterization of causal agents; develop understanding of relationship; molecular probes for viral diseases; diagnostics and resistance; virus-vector specificity and interactions.	Yr. 2: Continue with biological and molecular studies; continue cloning and characterization; begin antibody production. Develop detection and identification systems. Study virus-vector interactions: receptors, transmission, transformation, resistance	X		Whitefly-transmitted (WFT) geminiviruses from the US (Arizona, Florida, Texas), Mexico and Central America are under investigation in biological and molecular terms. Several WFT geminiviruses in Florida have been identified in bean, cabbage, tomato and weed species and compared at the nucleotide level at two sites in the genome. WFT geminiviruses from both new and old world sites have been studied and compared at the nucleotide level in the most conserved region of the coat protein gene. A tree based on this data show that viruses group primarily with respect to host plant as compared to the geographic partitioning observed when the entire capsid gene is used for the analysis. A sequence database has been established with these DNA sequences to which additional data will be added. Predictions about virus relationships will facilitate the identification and implementation of resistance strategies which rely on traditional breeding or engineered approaches. Virus-vector interactions are being studied in an attempt to understand the role of geminivirus-whitefly specificity and the underlying mechanisms. A morphological road map of whitefly anatomy at the EM level is being developed. Mouthparts and associated organs in *B. tabaci* are similar in structure to those found in aphids. The salivary glands and the digestive system have been observed in detailed morphological studies. In situ DNA hybridization is underway to localize virions in the vector in time course feeding studies. Virus-specific antiserum is being applied to localize virions in plant tissues and in the whitefly vector.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
B.8 Study epidemiological parameters: vector population dynamics; disease thresholds; identify sources of inoculum, distribution, severity, and prevalence of pathogens. Correlate efficiency of transmission with biotypes, diversity and parameters of cropping systems.	Yr. 2: Continue to investigate epidemiological parameters; begin to establish diagnostics; identify key isolates for in-depth characterization; study vector-host plant interactions.	X		Used polymerase chain reaction (PCR) to detect various plant pathogens such as tomato mottle geminivirus and tomato yellow leaf curl geminivirus. Determined that biotype A could transmit lettuce infectious yellows (LIYV) more effectively than B biotype. Result of reduced transmission of LIYV has been larger yields in certain crops beeause A biotype has a reduced population. The effect of different insecticidal regimes on epidemiology of tomato mottle virus in Florida was studied. Transmission characteristics and virus vector relationships of the old world virus, TYLCV (Egyptian strain) were investigated. Characteristics were like those observed thus far for other WFT geminiviruses.
B.9 Study mating and oviposition behavior.	Yr. 2: Determine factors, environmental and biological, that affect mating; determine factors affecting oviposition site selection and fecundity.	X		The effects of phosphorus nutrition and leaf age on SPW host selection were studied in cotton seedlings; phosphorus deficiency reduced oviposition on young leaves significantly in greenhouse and humidity chambers. Host acceptance was associated with low leaf sucrose concentrations (greenhouse), low total sugars and high leaf water (growth chambers). Suggests that factors affecting plant osmotic potential impact cotton susceptibility to SPW.
B.10 Determine factors influencing host plant selection and host acceptance.	Yr. 2: Isolate, identify chemicals and other cues involved; continue studies of host selection and acceptance.	X		Host preference was positively correlated to the abundance/length of vascular bundles per unit leaf volume. The preferred habitat is the under side of the leaf and this characteristic may be related to the shorter distance to vascular bundles from the lower compared to the upper leaf surface. Although leaf surface pubescence was an important factor in ovipositional behavior which resulted in females choosing the lower leaves which have fewer leaf hairs for deposition of 90-95% of eggs laid, negative geotropism was the overriding factor influencing oviposition on lower vs. upper leaves. Acceptability of host plant feeding sites, based on oviposition rates, was greatest on youngest leaves compared to older leaves or cotyledons. High osmotic potential of leaves was positively correlated with adult whitefly acceptability of the host plant.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
B.11 Identify plant nutritional and defensive responses to SPW and their effects on SPW and natural enemies.	Yr. 2: Isolate and characterize induced protein, enzymes, or compounds.	X		A minimum of eight different proteins (four different Mr's) were isolated from plants colonized by the 'B' biotype. At least six other proteins of three different Mr's appear to be suppressed by SPW B biotype feeding on sweet sugar pumpkin. Measurements of chitinase activities show an inverse relationship with the length of SPW B biotype feeding time, i.e., the longer the plant is a host for SPW, and the more progressive the silverleaf symptom, the lower the amount of chitinase activity.

RESEARCH SUMMARY

Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

Compiled by

J. K. Brown and R. T. Mayer

From studies on feeding behavior and location adult whiteflies feeding on plants, it appears that lower surfaces of the young leaves of most plant species tested are preferentially selected among other locations on the plant. Adult whitefly behavior was correlated negatively to geotropic factors, and positively in response to leaves with the greatest osmotic potential. Feeding sites were concentrated in areas containing vascular bundles. Adult whiteflies prefer sites where vascular bundles were closer to the leaf surface, adding additional credence to the observation that the under surface of the leaf is the optimal ecological niche for *B. tabaci*. Reproductive capabilities (fecundity) and development times on different hosts indicated cucurbits were among the most important reproductive host plants.

The propensity of whiteflies to inhabit the undersides of leaves has contributed to the problems associated with honeydew contamination of cotton lint and leaves below the feeding site. Analysis of the sugar composition of whitefly honeydew indicates that the major contributing factors in honeydew involved in the contamination problem are trehalulose and sucrose. These sugars can be removed enzymatically under experimental conditions, and although not commercially applied at the present, efforts are underway to adapt this process to the commercial removal of honeydew from fibers prior to the ginning process.

Ultrastructural studies of the cuticle of whitefly nymphs were made. Egg stalks were found to have thick multiple layers of fibrous material in the wall, but are devoid of cytoplasm. Mycetome-like organs containing prokaryotic-like and pleomorphic subsets of microorganisms were observed in immature instars, and at the distal tip of each egg as observed previously in other Homopterans. Attempts to cure adults of suspect endosymbionts by antibiotic treatment resulted in a reduction in the vigor of the offspring of treated adults, and in the intensity of phytotoxic silvering of squash leaves. It is not yet clear whether the putative microbial endosymbionts play a role in the induction of phytotoxic phenotypes in certain plant species. These disorders are characterized by autolysis of mesophyll cells at nymphal feeding sites, and by the presence of two proteins, 31K and 70K daltons, and the disappearance of a 60K protein typically found in squash plants infested by the 'B' biotype (*B. argentifolii*).

Composition of surface lipids and waxes on external surfaces of adults were investigated, and there was no apparent affect by host plant on composition for males or females. The predominant wax esters were C4,6 and the major acid and alcohol moieties in the esters were C20 and C26 length chains, respectively.

Ultramicroscopic level studies of the anatomy and morphology of the mouthparts, associated organs, and digestive system of the adult whitefly indicate that the mouthparts and gut are similar to those of aphids. Two mandibular and two maxillary stylets are present, and the food canal is separated from the salivary canal in cross sections of adult whitefly stylets. The esophagus, filter chamber, midgut, and hindgut are present and the hindgut is lined by a thin layer of squamous-like cells. The accessory and primary salivary glands have been visualized, and are proposed to play a role in virus selectivity. The underlying cellular and molecular mechanisms of virus-vector specificity are under investigation.

An epidemic in bean in Florida has been shown to be caused by a whitefly-transmitted (WFT) geminivirus, previously associated with epidemics in bean in the Caribbean Basin. The tomato mottle virus affecting

tomato in Florida since 1988 is being characterized in biological and molecular terms. Polymerase chain reaction (PCR) based methods are being applied to the epidemiology of the tomato yellow leaf curl virus in Egypt and the tomato mottle virus from Florida through the development of the capability to detect the viruses in both plants and the insect vector.

Numerous WFT geminiviruses from the US, Mexico and the Caribbean Basin are under investigation to determine biological and molecular properties that may be useful in understanding the diversity and the distribution of the viruses, and to develop fingerprints for rapid identification that will be useful in epidemiological studies and ultimately in prioritizing the viruses against which resistance programs must be directed. Polymerase chain reaction has been applied to the amplification of a conserved fragment of the coat protein gene and the establishment of a sequence database containing these sequences. The database may be used to catalog and compare additional WFT geminiviruses from worldwide locations to better understand the magnitude of the diversity and distribution of these viruses in terms of crop improvement approaches and for regulatory purposes. DNA sequence information is under analysis to determine if the targeted gene fragment will yield useful phylogenetic information about the WFT geminiviruses. Efforts to develop crop improvement strategies involving traditional breeding and genetic engineering approaches to reduce the impact of WFT geminiviruses in vegetable and fiber crops are underway.

The new 'B' biotype (*B. argentifolii*) was shown to be a poor vector of the clostero-like lettuce infectious yellows virus (LIYV), previously a serious virus pathogen affecting many crops species in the desert Southwest of the US. These data may explain why the incidence of LIYV incited disease has decreased since the introduction of the 'B' biotype into Arizona and California in about 1989. In contrast, an unprecedented increase in diseases caused by WFT geminiviruses is directly associated with the recent dispersal and now widespread distribution of the 'B' biotype in the US and adjacent locales in Mexico and the Caribbean Basin; hence the 'B' biotype appears to be an effective vector of WFT geminiviruses indigenous to these New World sites.

Biological and molecular studies are underway to better understand the diversity among whiteflies presently referred to a *B. tabaci* from numerous locations, worldwide. Differential non-specific esterase and RAPD's markers have been applied to the study the distribution of different putative whitefly biotypes/collections. Results of both studies indicate that there is a greater degree of genetic diversity than previously thought. These same approaches have been applied to study the distribution of the 'B' biotype (*B. argentifolii*), and this new whitefly is now known to be present in all of the Americas and Caribbean Basin, in greenhouses in Europe, in the Mediterranean Basin, the Middle East, and Japan. It was concluded that the application of RAPD's markers to investigate differences between whiteflies at the species and subspecies levels did not yield genetic information that would allow for predictions about whitefly speciation and phylogeny. Studies are in progress in which nuclear and mitochondrial DNA markers are under investigation in order to address these questions. Based on the evaluation of biological, morphological, and genetic characteristics of the indigenous 'A' and introduced 'B' biotype biotypes, the 'B' biotype has been proposed to constitute a separate species, *B. argentifolii*, the silverleaf whitefly.

C. Chemical Control, Biorationals, and Pesticide Application Technology

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: July - September, 1993

SMALL PLOT TRIAL WITH CANDIDATES FOR CHEMICAL CONTROL OF SPWF IN COTTON

A trial with candidates for chemical control of SPWF was conducted at a site in Maricopa, AZ, with small plots (5 CRBD replicate plots = 0.052 ac). Agents tested included: two pyrethroids, bifenthrin (Capture™) and fenpropathrin (Danitol™), with the latter tested with the organic phosphate acephate (Orthene™) as a synergist; a six-way synergist test with all combinations of esfenvalerate (Asana™), piperonyl butoxide (Butacide 8 EC™) and chlorpyrifos (Lorsban™); insect growth regulators (IGRs), azadirachtin (Azatin™), a partially-hydrated azadirachtin, fenoxycarb, and two rates of pyriproxyfen); and the numbered compound CGA 215944).

Data for mean egg numbers per cm^2 of leaf for the last three applications of 6 applications showed significant control ($P \leq 0.05$) from a block of untreated plots and from each other within the following groupings in order, respectively by highest percent reduction from the control block listed first: 1) fenpropathrin/acephate, CGA 215944, the 3-way mix piperonyl butoxide/esfenvalerate/chlopyrifos, 2) esfenvalerate, piperonyl butoxide/esfenvalerate, 3) partially-hydrated azadirachtin, piperonyl butoxide, bifenthrin, piperonyl butoxide/chlorpyrifos, chlorpyrifos, azadirachtin, and 4) pyriproxyfen-higher rate, fenoxycarb, and pyriproxyfen-lower rate.

Data for large immatures per cm^2 of leaf for the last three of 6 applications showed significant control ($P \leq 0.05$) from a block of untreated plots and from each other with the following groupings in order, respectively by highest percent reduction from the control block listed first: 1) pyrifroxyfen-higher rate, 2) fenpropathrin/acephate, pyriproxifen-lower rate, the 3-way mix piperonyl butoxide/esfenvalerate/ chlorpyrifos, 3) bifenthrin, CGA-215944, 4) piperonyl butoxide, 5) and esfenvalerate.

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DATES COVERED BY REPORT: July - September 1993

PLOT TRIALS WITH BUPROFEZIN FOR CHEMICAL CONTROL OF SPWF IN COTTON

Trials with the insect growth regulator buprofezin, a chitin inhibitor, for chemical control of SPWF were conducted at a site in Maricopa, AZ, with three plot sizes: large = 2 Ac, 1 plot; medium = 0.115 Ac, 1 plot; and small = 0.023 Ac, 10 plots (5 plots X 2 rates) in a CRBD of 30 plots.

Data for mean egg numbers per cm^2 of leaf for 6 applications showed significant control ($P \leq 0.001$) from a block of untreated plots and from each other, respectively by percent reduction from the control block: 85% for the large plot, 52% for the medium plot, and 44% for the small plots.

Data for mean large immatures numbers per cm^2 of leaf for 6 applications showed significant control ($P \leq 0.001$ for large and medium plots, $P \leq 0.05$ for small plots) from a block of untreated plots and from each other respectively by percent reduction from the control block: 98% for the large plot, 88% for the medium plot, and 71% for the small plots.

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DATES COVERED BY REPORT: July - September, 1993

PLOT TRIALS WITH AMITRAZ FOR CHEMICAL CONTROL OF SPWF IN COTTON

Trials with amitraz, a triazapentadiene compound, in combination with endosulfan or bifenthrin or fenpropathrin, and alone for chemical control of SPWF were conducted at a site in Maricopa, AZ, with two plot sizes: large = 1-1/2 Ac, 1 plot with 3 subplots each, and small = 0.023 Ac, 10 plots (5 plots X 2 rates) in a CRBD of 30 plots. Amitraz alone was evaluated only in the small plots.

Data for mean egg numbers per cm^2 of leaf for the large plots for the first 3 applications of 6 showed significant control ($P \leq 0.001$) from a block of untreated plots, respectively, by percent reduction from the control block: 96% for amitraz/endosulphan, 94% for amitraz/biphenthrin, and 96% for amitraz/ fenpropathrin; similarly, the last 3 applications were 95%, 97%, and 97%, respectively.

Data for mean large immature numbers per cm^2 of leaf for the large plots for the first 3 applications of 6 showed significant control ($P \leq 0.001$) from a block of untreated plots, respectively, by percent reduction from the control block: 86% for amitraz/endosulphan, 79% for amitraz/biphenthrin, and 78% for amitraz/ fenpropathrin; similarly, the percent reduction for the last 3 applications for all 3 treatments were 95%.

Data for mean egg numbers per cm^2 of leaf for the small plots for the first 3 applications of 6 showed significant control ($P \leq 0.001$) from a block of untreated plots, respectively, by percent reduction from the control block: 64% for amitraz and 70% for amitraz/endosulphan, similarly, the last 3 applications were 52%, and 82%, respectively.

Data for mean large immature numbers per cm^2 of leaf for the small plots for the first 3 applications of 6 showed significant control ($P \leq 0.001$) from a block of untreated plots, respectively by percent reduction from the control block: 76% for amitraz and 68% for amitraz/endosulphan, similarly, the last 3 applications were 42% and 82%, respectively.

These trials showed combinations of amitraz to be very efficacious against SPWF in large plot trials.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: July - September, 1992 and 1993

USE OF HYDRAULIC SPRAYERS FOR GROUND CONTROL OF SPWF IN COTTON

Applications were made with a 4-row spray boom with drops designed to spray the undersides of cotton leaves (see Akey et al., Proc.Beltwide Cotton Conferences 1992). The boom was attached by a 2-point hitch to a John Deere Hi-Cycle™ 600 sprayer. Two spray trials were run for the 1993 SPWF season in upland cotton DPL 5415. In the first trial, twenty one nozzles (TeeJet, Spray Systems Inc.) per row (3 sets of nozzles at 3 positions per side on swivel-heads adjusted at various upward angles with 3 overhead nozzles directed downward) were used to obtain leaf coverage at 1) 70 psi (at nozzles) to apply a rate of 60 gal/ac and 2) at 100 psi to apply a rate of 30 gal/ac. In the second trial, the same boom and drop setup was used but with only 7 nozzles per row; however the pressure was increased to 400 PSI (at nozzles) but the rate of 30 gal/ac was maintained. The rates at different pressures were obtained by using different cones and disks in the spray heads. Additionally, mainline filters followed by slotted or screened filters in the spray heads were used to keep the nozzles from clogging.

Spray efficacy was determined by 1) efficacy of fenpropathin/(acephate or amitraz) insecticides applied against SPWF large immatures as measured by percent reduction from untreated control blocks, 2) by leaf coverage of upper and lower surfaces of main leaves at positions from the terminal down as leaves 5, 7, and 9, as determined by dye as follows: field application with the sprayer of either a 1% solution of Leucophor EFR Liquid dye (Sandoz Chemical Corp.) or fluorescein dye (Sigma Chemical Co.) and then use of ultraviolet color photography of leaf samples 10-12 hr after sampling; and digitization by video to obtain percent coverage, droplet pattern, and size. , and 3) true particle size as determined by microscopic examination.

Insecticidal efficacy against large SPWF immatures at 30 gal/ac at 100 psi was 60% compared to 99.8% at 60 gal/ac at 70 psi under similar conditions. In contrast, applications of 30 gal/ac at 400 psi gave 95% reduction. Coverage, as determined by dye application, showed leaf undersides and top surfaces to be well covered for all three of the canopy levels studied for 60 gal/ac at 70 psi and 30 gal/ac at 400 psi. In contrast, coverage was about half that for 30 gal/ac at 100 psi.

At 400 psi, microscopic examination showed a particle size range of 65 to 150 microns. No damage to flowering structures, bolls, nor foliage was observed by the 400 psi spray with this droplet size range. Also, the positioning of 6/7 of the spray in the cotton canopy itself, reduced drift to the point that spray operations were able to be conducted under higher wind conditions than usually acceptable for ground application.

A commercial application of ground spraying for season-long pest control in may be feasible by use of a 24-row plant / skip 4-row planting scheme. This would allow spray equipment to enter fields requardless of irrigation schedules and meet "set aside" requirements for regulatory purposes.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: July - September, 1993

WHOLE SEASON ROTATIONAL PESTICIDE SYSTEM FOR CONTROL OF SWEETPOTATO WHITEFLY IN COTTON

SUNDANCE FARMS of Coolidge, AZ was chosen for the study site, DPL 5415 cotton was used, and irrigation was by furrow. The planting design was solid without skip rows. A field was divided into four-5 ac blocks. Each block was subdivided into 5 replicates by strip with 5 subplots within each replicate for a total of 25 sampling points within each block.

For early season control, the first two 5-ac blocks received Aldicarb (Temik) at seed 5 lb and then side-dress of 15 lb. On the first 5-ac block (Rotation I), pink bollworm pheromone as NOMATE) was put out with chlorpyrifos (LOCK-ON) 3 times (weekly) against PBW at Pin-head Square and NOMATE alone as needed dependant on PBW pressure. On the second 5-ac block (Rotation II) that received aldicarb (Temik), three applications were made with thiodicarb (Larvin) at pin-head square against Pink Bollworm (PBW). On the third 5-ac block (Rotation III), oxamyl (Vydate) with methomyl (Lannate) was applied for early season pest and PBW control. The fourth block was a best agricultural practices per the farm protocols and did receive aldicarb (Temik) as a side dress.

For mid-season control on the first 3 blocks (rotations I,II,and III) , biorational agents were chosen for arthropod control as needed to allow beneficials to increase their population numbers. These agents, primarily targeted toward lepidopterous pests, included: BT (as Biobit), Diflubenzuron (Dimilin), Potassium salts of fatty acids (M-PEDE), and petroleum oils (Saf-T-Side oil and JMS Stylet oil) used as needed during June and July. Adult SPWF numbers of 2-3 per plant or large immature numbers of 3-4 per leaf with highest immature count was considered an action threshold.

For late season control, when the SPWA was exceeded, amitraz (Ovasyn) with endosulfan (Thiodan, 2C) was applied twice at weekly intervals in rotation blocks I- III with block 4 receiving the regular farm schedule/applications. The pyrethroid, esfenvalerate (Asana) was applied twice. Though not necessary in this experiment, if control had been still needed, a different class of insecticide would have been used.

Cotton was terminated expediently (about 4 nodes above 1st cracked boll) and harvest aids were used as needed, Ethephon (Prep) and thidiazuron (Dropp).

Yield data and lack of stickiness was similar between the 4 blocks and the rest of the field. This management program was aimed to use true integrated pest management (IPM) and to present methods of insecticide usage to promote biological control by beneficials and prevent insecticide resistance from occurring.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

DATES COVERED BY REPORT: 1992 Cotton Season

PYRIPROXYFEN (S-71639), AN IGR FOR WHITEFLY CONTROL

Pyriproxyfen (S-71639) is not a conventional insecticide but an insect growth regulator (IGR). S-71639 is an IGR which mimics the naturally occurring juvenile hormone (juvenile hormone mimic). Application to certain insects disrupts the hormonal balance, and causes a failure of ecdysis and/or sterility. Depending on insect stage growth, S-71639 may cause inhibition of metamorphosis, inhibition of embryogenesis and inhibition of reproduction. S-71639 does not affect general larval development but arrests larval metamorphosis on certain insects such as whiteflies, scales and leafminer moths.

S-71639 is very effective in controlling a number of insect pests: armored scale, pear psylla, codling moth, oriental fruit moth and several whitefly species including the sweetpotato whitefly (*Bemisia tabaci*). S-71639 is currently registered in Guatemala, Turkey, and Sudan for control of the sweetpotato whitefly at 20 to 40 grams ai/A and in South Africa and Zimbabwe for scale insects in citrus. Registrations are pending in Denmark, France, Belgium, Spain and Portugal for agricultural and horticultural uses. Further, S-71639 is registered for public health use as S-31183 (Synonym) in Japan, Spain, France, Argentina, and China and is pending in the USA.

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DATES COVERED BY REPORT: 1992 Cotton Season

FENPROPATHRIN PLUS ACEPHATE FOR WHITEFLY CONTROL

A tank mixture of fenpropathrin plus acephate (0.22 + 0.56 k/ha) was tested in several trials in AZ/CA in 1992 to determine efficacy on strain B of sweetpotato whitefly (*Bemisia tabaci* Gennadius) in cotton. All testing was with ground equipment and the number of applications in the tests varied from 3 to 10 on either a 7 or 14 day interval.

The fenpropathrin plus acephate tank mixture was consistently a top performer in these trials as evidenced by evaluations of adult, egg, and nymphal forms of sweetpotato whitefly and by the significant yield increases produced compared to the untreated controls. In the only trial that was applied on a 14 day interval, the fenpropathrin plus acephate tank mixture had yields significantly greater than all other products being tested.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: October 1992 - September 1993

EVALUATION OF INSECTICIDE APPLICATION EQUIPMENT FOR SPRAY DEPOSITION AND EFFICACY AGAINST *BEMISIA TABACI* ON TOMATOES

Five sprayer types applying insecticidal soap and *Bacillus thuringiensis* were compared for spray deposition and efficacy against *Bemisia tabaci* (silverleaf whitefly) and lepidopterous pests including *Spodoptera exigua* and *Heliothis* spp.

Sprayers used were the Degania, a high output (54 GPA) sprayer using an inflatable boom, a Control Droplet Applicator using a spinning disk and oscillating fans to distribute a very low volume of spray (1.8 GPA) and an electrostatic sprayer which electrically charges the droplets and expels them with an air blast. The electrostatic was tested with the charge on and off applying 12 GPA in both cases. A standard conventional type sprayer was also included in the test, which used 3 twin-jet type nozzles per row and had an output of 60 GPA.

Spray deposition was measured using computer scanned water sensitive papers which were attached to the tomato leaves near the top of the plant, and ultraviolet photography of fluorescent dye applied through the sprayers directly onto the leaves. In addition, a spectrophotometric assessment of food dye which was washed off the leaf, gave information on the concentration of material applied to both dorsal and ventral sides of the leaf.

There was no significant difference between the sprayers with respect to percent coverage assessed by the water sensitive papers for either the dorsal or ventral surfaces. When spray deposition was measured by the more sensitive leaf washing method, the Degania and Controlled Droplet Applicator had significantly less coverage to the dorsal surfaces than the other sprayers tested, but was not significantly different on the ventral surfaces.

Whitefly and lepidopterous pest populations were too low in this early spring tomato experiment to achieve sufficient insecticide efficacy data using different sprayers.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: September 1992 - September 1993

UREA, ALEITTE AND ORGANIC FERTILIZER EFFECTS ON SILVERLEAF WHITEFLY POPULATIONS

Outbreaks of the silverleaf whitefly (SLW) in the southwest regions of the United States pose a major threat to cotton production. The SLW ability to quickly develop resistance to insecticides has made it necessary to develop methods to manage this insect in a way that would reduce and delay insecticide for their control. In field experiments in 1992, we showed that foliar applications of urea and Aleitte reduced levels of whitefly eggs and nymphs and provided a yield of ginned lint greater than that of untreated controls. In 1993, our field experiments indicate that we should be able to delay applying an insecticide treatment for SLW control until the third week of July by applying foliar applications of natural, organic fertilizer, oils and/or urea. This may be an alternative to using synthetic insecticides on early season cotton and therefore slow the development of resistance to insecticides by SLW. In further investigations in a greenhouse experiment we documented the effects of low, medium, and high nitrogen in cotton on development and honeydew production by the whitefly, *Bemisia argentifolii* Bellows and Perring. Nitrogen status of cotton plants was manipulated by irrigation with 0.5, 2.5, or 5.0 mmol/liter nitrogen fertilizers. Although the fertilization treatments produced large differences in plant growth, subtle differences were found in whitefly development. No differences among treatments were found in stage-specific survival or the time whiteflies spent in each stadium. Time to adult emergence by whiteflies increased with decreasing nitrogen fertilization. Although early-instar whiteflies on high nitrogen plants initiated the production of honeydew droplets before whiteflies on medium and low nitrogen treatments, they subsequently generated fewer droplets through 24 h periods.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

DATES COVERED BY REPORT: October 1, 1992 - September 30, 1993

AIRCRAFT SPRAY NOZZLES FOR MINIMIZING SPRAY DRIFT AND OPTIMIZING SPRAY DEPOSITION ON COTTON

Aerial spray drift and deposition experiments were conducted with two different types of spray nozzles, whirl-type hollow cone and narrow-angle flat spray, on a turbine powered agricultural aircraft. Measurements were made of spray deposition on the tops and bottoms of leaves in the top and mid-canopy of cotton plants and for the downwind drift of spray from the intended swath at airspeeds of 120, 135 and 150 miles/h. The flat spray nozzles provided more deposit on both the tops and bottoms of plant leaves than the hollow cone nozzles, but the hollow cone nozzles at an airspeed of 150 miles/h provided a higher droplet density than the other treatments. Spray drift at 140 m downwind of the flight path was significantly greater for the hollow cone nozzles at 150 miles/h than all other treatments except for the same nozzles at 135 miles/h. Spray drift at 140 m was significantly less for the flat spray nozzles at 120 miles/h than for all other treatments except for the same nozzles at 135 miles/h. The amount of airborne spray at 140 m was strongly influenced by both nozzle type and airspeed (greater for the hollow cone nozzles and for the higher airspeeds) and the drift cloud extended more than 10 m above ground at 140 m downwind for all treatments. The results indicate a comparative advantage for the lower airspeeds and the flat spray nozzles in both drift reduction and increased spray deposition on plant leaves.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

DATES COVERED BY REPORT: October 1, 1992 - September 30, 1993

AERIAL SPRAY DEPOSITION STUDIES FOR SWEETPOTATO WHITEFLY CONTROL IN COTTON

A season-long study of aerial application methods for controlling sweetpotato whitefly was conducted near Maricopa, Arizona. Similar research last year showed that aerial systems that caused increased air velocity and turbulence in the crop canopy when spray was deposited resulted in increased deposits on the underside of leaves where whitefly locate. Treatments in the 1993 studies included rotary atomizers, winglets, trumpet nozzles, and CP nozzles. In studies prior to the season-long experiment, spray deposition was measured on leaves and on water-sensitive paper attached to leaves at top- and mid-canopy locations. Water-sensitive paper was used in a similar manner to monitor spray deposition each time the field-scale treatments were applied. Danitol (0.2 lb AI/ac) and orthene (0.5 lb AI/ac) were used in the efficacy studies. Both the preliminary deposition study and the season-long efficacy study results show that none of the treatments were superior in delivering spray active ingredients to target plants, but the treatments were considerably different in the spray droplet spectrums that were deposited on top- and mid-canopy leaf surfaces. Droplet size was the dominant factor in giving highest sweetpotato whitefly mortality; the treatment that deposited the smallest droplet spectrum gave the best season-long control of whitefly in these studies.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology.

DATES COVERED BY REPORT: October 1, 1992 - September 30, 1993

AERIAL SPRAY APPLICATION SYSTEMS/PERFORMANCE FOR SWEETPOTATO WHITEFLY CONTROL

Two agricultural aircraft were planned for use in aerial spray test on cotton infested with sweetpotato whitefly near Maricopa, AZ. Preliminary studies with these aircraft were carried out using the ARS spray deposit analysis system to establish spray pattern distribution uniformity and swath width. These parameters were evaluated for an ARS AgHusky aircraft equipped with rotary (ASC) atomizers and Chimavir winglets. Similarly, a Custom Farm Services Turbine Thrush (Stanfield, AZ) was also evaluated with conventional (CP) and trumpet nozzles.

An aerial, electrostatically charged spray test was carried out over cotton to test for improved penetration and deposition. An ARS Cessna 206 aircraft equipped with 20 spinner spray charging nozzles was used in the study. The test objective was to evaluate three spray charging treatments/protocols. These were; (1) No charging (NC), (2) Dual polarity charging (DP), and (3) Alternating polarity charging (AP). Deposit analysis obtained from leaf washing showed that the spray deposited with DP was significantly higher than AP and NC. Spray deposits on the top of leaves at the top of the canopy were 4.43 times greater with DP than with NC. Spray deposits on the top of leaves at mid canopy were 2.22 times greater with DP than with NC. Spray deposits on the bottom of leaves at the top of the canopy were 0.91 times the deposits on the top of the same leaves with DP compared to 0.83 for NC. The AP protocol was better than NC but not as good DP.

The dual side leaf washers, designed 2 years ago for plant spray deposit removal, have easily passed another year of field use. These simple tools have continued to perform nicely and have required little maintenance. Efforts to interest someone to commercially build the leafwashers have continued and a CRADA is under development.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology.

DATES COVERED BY REPORT: 1993

EVALUATION OF INSECTICIDES BY CHEMIGATION AND GROUND APPLICATION TO CONTROL SWEETPOTATO WHITEFLY ON CUCURBITS AND TOMATOES

'Pavo' summer squash was treated six times at 5 to 6 day intervals with Thiodan 3EC (1.0 lb[AI]/acre) or Capture 2 EC (0.08lb[AI]/acre) applied by chemigation in Orchek oil (1 gal./acre). Capture gave almost complete control of silverleaf while 17 to 36% of the Thiodan treated plants showed silverleaf. Untreated plants were 100% affected.

On hand-treated plants in the field, best silverleaf reduction of silverleaf on zuccini squash and immature SPW on watermelon was with Applaud 40 SC (0.38 lb[AI]/acre), and Admire (0.045 lb[AI]/acre).

In the greenhouse significant reduction of SPW immatures was obtained with Thiodan 3EC 1.0 lb[AI]/acre)* + 1% oil mixture, 1% oil, Ovasyn 1.5 EC (0.25 lb[AI]/acre), Admire 2F (0.1 lb[AI]/acre), 1% Tide, 1% M-Pede, Fenoxycarb (0.25 lb[AI]/acre), and Decis 2.5 EC (0.013 lb[AI]/acre).

* Rate in greenhouse based on a volume of 50 gal/acre of water.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology.

DATES COVERED BY REPORT: May - November, 1993

FIELD TRIALS OF ELECTROSTATIC SPRAYERS ON TOMATOES, COTTON AND CAULIFLOWER

Field trials to compare deposition and efficacy among several commercial spraying technologies were conducted in tomatoes, cotton, and cauliflower.

The application techniques compared during the trials were: two types of air-assisted electrostatic sprayers (both were operated with the charging circuit on, and off), hydraulic nozzles in combination with an air curtain (intended to increase canopy penetration), a controlled-droplet application system, and hydraulic nozzles dispensing low and high volumes of carrier.

Three methods were used to assess sprayer deposition. These were: attaching water sensitive cards to dorsal and ventral leaf surfaces, followed by spraying and then scanning to determine the percentage of card surface covered by droplets; washing dye deposited during spraying from the dorsal and ventral leaf surfaces, followed by analysis of the washate in a micro-spectrophotometer; and photographing the sprayed dorsal and ventral leaf surfaces under ultraviolet light (which illuminates a phosphorescent dye in the spray solution), followed by scanning to determine the percentage of leaf surface covered by droplets.

For each series of trials, statistically significant differences in deposition were not consistently detected among sprayers. Generally, deposition decreased farther into the canopy, and was consistently less on the ventral leaf surfaces for all sprayers. In most cases, consistent differences in efficacy were not detected among sprayers.

This research indicates that properly adjusted and operated hydraulic sprayers can provide deposition and control equal to alternative technologies. The advantage of alternative technologies appears to be decreased volumes of carrier required for operation.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology.

DATES COVERED BY REPORT: 1993

SWEETPOTATO WHITEFLY ACTION AND ECONOMIC THRESHOLDS

Studies leading to the development of action and economic thresholds for the sweetpotato whitefly B strain (SPW), *Bemisia tabaci* Gennadius, on cotton were initiated in the Imperial Valley, CA, in 1993. The insecticide mixture of fenpropathrin (Danitol® 2.4EC, α-Cyano-3-phenoxybenzyl 2,2,3,3,-tetramethyl-cyclopropanecaboxylate) and acephate (Orthene®, O,S-Dimethyl acetylophosphoramidothioate) was used as the control agent. Weekly application schedulings were initiated on a series of cotton plots each week beginning on 28 April. The first applications were made when cotton was in the 1 to 2 true leaf stage of plant growth. The last application series was initiated on 3 August when whitefly populations were extremely high. Cotton lint yields from the plots and numbers of insecticide applications were subjected to regression analysis. The number of insecticide applications resulting in maximum lint yield was determined and used in relation to SPW population counts. Results showed that the estimated action thresholds were: eggs 0.64, nymphs 0.22, and pupae 0.0065 per cm^2/leaf; or 2.22 adults per cm^2 of yellow trap surface. The resistance ratio of SPW adults to the insecticide mixture averaged 3.6 compared to the laboratory-reared susceptible strain. A resistance ratio of 5.0 is considered significant. The low resistance ratio after 15 applications of the insecticide mixture to some plots increases the reliability of the estimated action thresholds.

In consideration of the low number of pupae found on leaves, frequent dispersal of adults and lint contamination with honeydew excreted by SPW, number of nymphs/cm^2 of leaf tissue appears to be the best SPW developmental stage to use as an indicator of the action threshold.

Increasing SPW populations were significantly correlated to increased lint stickiness and negatively correlated with cotton lint yields.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: 1992-1993

CHEMICAL EFFICACY TESTS FOR SWEETPOTATO WHITEFLY CONTROL

1992: Seven insecticides were evaluated in 9 treatment combinations for efficacy against the sweetpotato whitefly (SPWF). Five different classes of chemistry were represented by these compounds, which were compared to an untreated check. The infestation was characterized as severe, >300 SPWF/sq.in. Three ground applications (25 GPA) were made in August at the onset of "stickiness". Three treatments compared favorably with the check, but only after 3 applications: Danitol® (.2 lb. ai/A) + Orthene® (.5), Capture® (.1) alone, and Capture (.1)+Ovasyn® (.25). Intermediate control was achieved with endosulfan (1.0) +Ovasyn (.25). The remaining treatments did not significantly reduce SPWF eggs or nymphs compared to the untreated check given the extreme conditions of this test: endosulfan (.75), Asana® (.05), Ovasyn (.25), Vydate® (.75)+ Asana (.5), and Vydate (.75).

1993: Eleven combinations of insecticides were compared for efficacy against all SPWF stages. Rather than singular compounds, combinations were examined, because previous studies have shown these to be necessary to achieve SPWF control. Treatments were designed to be ca. economically equivalent with costs of ca. $13-$17 per application. Pyrethroid rates were adjusted accordingly, while tank-mix partners were applied at the rate of 0.5 lb ai/A. Applications were by ground, broadcast, over-the-top, at 20 GPA for a total of 5 applications and 5 evaluation dates. Application initiation was at ca. 10 adults/leaf. Microscopic leaf counts (4th or 5th mainstem leaf below the terminal) were used to evaluate immature stages, while adult evaluations were made by in-field leaf turns. Combinations were ranked in overall descending SPWF efficacy: Danitol (0.15) + Orthene ≤ Danitol (0.15) + Lorsban® < Karate® (0.04) + PenncapM® = Scout Xtra® (0.024) + Orthene = Asana (0.05) + Curacron® = Asana (0.05) + Orthene < Asana (0.05) +Phaser® = Scout X-tra (0.024) + Phaser® = Asana (0.05) + Lorsban = Asana (0.05) + Vydate < Untreated Check. Combinations containing Orthene had the highest yields and were correlated with better Lygus suppression. Lygus populations were very high in this test and were at least as likely to have impacted yields as SPWFs in this study. Top yields were over 4003 lbs seed cotton/A (3.27 bales) with the untreated check at 1512 lbs seed cotton/A (1.2 bales).

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: 1993

FIELD EVALUATION OF AN INSECT GROWTH REGULATOR, BUPROFEZIN, FOR CONTROL OF THE SWEETPOTATO WHITEFLY, *BEMISIA TABACI*

Two rates of buprofezin, ["Lo" (0.25 lb ai/A) & "Hi" (0.38 lb ai/A)], were compared against Ovasyn® (.25) and the standard pyrethroid combination Danitol® (.2) + Orthene® (.5). A combination of buprofezin-Hi + endosulfan (.75) was also included in the test. Endosulfan was used on an as needed basis to achieve some level of SPWF adult suppression, because buprofezin alone lacks visible adult activity. Applications were by ground, broadcast, over-the-top, at 20 GPA for a total of 6 or 7 applications. Initiation of IGR applications preceded the other 2 treatments by 1 week and were initiated at ca. 2.4 SPWF adults/leaf. The other two treatments, Danitol+Orthene and Ovasyn, began one week later at ca. 6.7 SPWF adults/leaf. Microscopic leaf counts (4th or 5th mainstem leaf below the terminal) were used to evaluate immature stages, while adult evaluations were made by in-field leaf turns. Predator and parasite populations were also monitored using standard sweeping techniques. When compared with the untreated check, Danitol+Orthene was the most effective treatment against all stages of sweetpotato whitefly. Among the other treatments, buprofezin+endosulfan controlled all stages, but not as well as Danitol+Orthene, and was considerably more effective than the 2 rates of buprofezin and Ovasyn. There was no effect of rate of buprofezin on SPWF control. Buprofezin alone and Ovasyn did not significantly suppress adult populations. Yields were affected by treatment; however, Lygus numbers within these plots were extreme. Danitol+Orthene had the greatest Lygus activity and yielded 4030.2 lbs seed cotton/A, while buprofezin+endosulfan yielded 2172.0 lbs seed cotton/A. All other treatments yielded amounts similar to the untreated plots which had 863.0 lbs seed cotton/A. The following is a general ranking of overall descending efficacy: Danitol+Orthene < endosulfan+buprofezin < buprofezin-Hi = buprofezin-Lo < Ovasyn < untreated check.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: April - September, 1993

AREAWIDE CONTROL OF SWEETPOTATO WHITEFLY, *BEMISIA TABACI*, ON COTTON IN PALOMA, AZ

A large-scale trial for the control of sweetpotato (silverleaf) whitefly, *Bemisia tabaci*, (SPW) was carried out in Paloma and Painted Rock near Gila Bend, Arizona, on approximately 6,156 ha of cotton during the 1993 season. Within the program area 40 fields were randomly selected for comparison with 15 fields in each of 2 locations outside the program. They were identified as check east (approximately 11 k northeast of the program) and check west (approximately 3 k west of the program).

Whitefly populations in both check areas were controlled according to individual grower protocol. On a weekly basis, adult counts were taken from all 4 edges and the centers of each field using the oil pan technique. Insecticides were applied aerially in the program area on the full field or edges based on population density recorded from pan samples. Insecticide combinations were rotated weekly in an attempt to reduce the potential for the development of pesticide resistance.

During the 16-week evaluation period SPW adults were significantly higher in check east and check west than the program area by 2- and 6-fold, respectively; eggs were higher by 3- and 39-fold, respectively; and nymphs were also significantly higher in check east and check west by 3- and 60-fold respectively. Ginning records for 1993 indicate approximately a 20% increase in yield in the program area versus 1992.

These results demonstrate that an area-wide approach, utilizing edge treatment where possible, based on extensive field sampling regimens represent an important integrated strategy in a successful whitefly control program.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: July 1, 1993-September 30, 1993

AERIAL SPRAY EFFICACY STUDIES FOR SWEETPOTATO WHITEFLY CONTROL IN COTTON

During the 1993 growing season, the efficacy of aerial delivery systems was evaluated for season-long control of sweetpotato whitefly (SPW) in commercial cotton fields near Maricopa, AZ. Aerial delivery systems evaluated were: rotary atomizers mounted on an airfoil spray boom on an AgHusky operated at 145 and 185 km/h; boom-mounted air deflectors known as Chimavir winglets; air ducts known as trumpet nozzles mounted on an Ayres Turbo Thrush operated at 1.5 and 3 m height and a conventional spray boom fitted with CP nozzles on an Ayres Turbo Thrush. Three sprays were made with Danitol 2.4E + Orthene 90S at 0.22 and 0.56 kg a.i./ha., respectively, for control of SPW. A fourth spray was conducted with Lorsban 4E + Asana XL 0.66E at 0.84 and 0.05 kg a.i./ha., respectively, for control of beet armyworm. The spray volume was 46.7 L/ha. Yellow sticky cards (YSC) were deployed at top and mid-canopy positions and were placed horizontally inside the row in random locations. Counts of nymphs were obtained from leaf plugs. Following the third spray, counts of SPW were taken in a producer control cotton to compare data with application treatments. The producer control cotton was commercially treated with Danitol + Orthene with a.i. rates ranging from 0.13 to 0.17 kg/ha and 0.57 to 0.59 kg/ha, respectively. Data suggest that counts of *B. tabaci* adults captured on YSC in the mid-canopy are better indicators of pesticide efficacy than those captured in the top-canopy, although significantly more SPW adults were captured in the top-canopy than in the mid-canopy (avg $4.32/cm^2 \pm 0.17$SE versus $1.62/cm^2 \pm 0.07$SE). The percentage reduction of large nymphs in the mid-canopy for the trumpet nozzle (175 km/h; 1.5 m) treatment was the lowest and decreased consistently over time. Mortality of large nymphs in the mid-canopy for the rotary nozzle (185 km/h; 1.5 m) treatment increased consistently over time. No single treatment produced consistently higher nymphal mortality either in the mid or top-canopy. Differences in the percentage reduction of large nymphs between treatments will be evaluated for possible functional relationships with spray deposit measurements such as spray coverage, droplet density and droplet size. Postspray adult numbers and viable eggs were significantly higher in the producer control cotton. Data suggest that Danitol + Orthene applied at the a.i. rate used here provided satisfactory control of SPW on cotton, irrespective of application hardware.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

DATE COVERED BY REPORT: 1993.

TOXICITY OF BIORATIONAL INSECTICIDES TO *BEMISIA TABACI*

Leaf-dip bioassays were conducted in laboratory to evaluate the toxicity of M-Pede, Sunspray ultra-fine spray oil, extract of *Nicotiana gossei*, and bifenthrin to *Bemisia tabaci* (Gennadius). Water was used as a control. *B. tabaci* adults used were maintained in greenhouse cultures on potted tomatoes (*Lycopersicum esculentum* Miller, 'Lanai'). Whitefly eggs were obtained by placing whitefly-free plants in a whitefly colony. Nymphs were obtained by caging plants bearing eggs until the appropriate stages were ready for treatments. Leaves were treated and numbers of dead and live adults, nymphs and pupae and empty pupal cases were recorded.

Bioassays with residues dried on leaves showed that Sunspray oil caused greatest mortality to adults for at least up to 5 d after treatments. Dry residues of bifenthrin at field rates or higher gave significant mortality at 2 h, but the effectiveness was significantly reduced at 24 h and thereafter. M-Pede and *N. gossei* extract were not effective against adults, while all insecticides were effective against young nymphs. Along with Sunspray oil and bifenthrin, M-Pede and *N. gossei* extract were effective against young nymphs even at very low rates. The two lowest rates of M-Pede were not effective against old nymphs, while all rates of *N. gossei* extract were effective against old nymphs and pupae. Sunspray oil was the only treatment effective against eggs, giving >60% mortality when applied at field rates or higher.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

DATE COVERED BY REPORT: 1993.

REPELLENCY OF BIORATIONAL INSECTICIDES TO *BEMISIA TABACI*

Laboratory and greenhouse repellency tests of M-Pede, Sunspray Ultra-fine Spray Oil, Garlic Barrier, extract of *Nicotiana gossei* and bifenthrin to *Bemisia tabaci* (Gennadius) were conducted using water as a control. *B. tabaci* adults were maintained in greenhouse cultures on potted tomatoes (*Lycopersicum esculentum* Miller, 'Lanai'). Greenhouse dual-choice repellency tests allowed adults to choose insecticide-treated or untreated plants. Leaves were sprayed to runoff, allowed to dry and placed randomly in the whitefly colony. Leaf-wheels, designed to offer adults multiple-choices of treated leaves, were placed in a whitefly colony in greenhouse tests or, in laboratory tests, were caged in a carton box with the top covered by transparent film.

Bifenthrin and Sunspray oil treated leaves had the fewest adults and eggs in all repellency tests, followed by M-Pede and *N. qossei* extract. Garlic Barrier appeared not to repel whiteflies under both greenhouse and laboratory conditions. In dual choice tests, *B. tabaci* adults again avoided plants treated with bifenthrin and Sunspray oil. Numbers of adults on leaves were significantly reduced for up to 7 d compared to controls. Significant repellency was obtained with *N. gossei* extract for up to 5 d. There was no significant reduction of adults in plants sprayed with Garlic Barrier. Most eggs were found on the water control, followed by Garlic Barrier, M-Pede, *N. gossei* extract, bifenthrin, and finally Sunspray oil. Numbers of eggs and adults per leaf were well correlated except for the bifenthrin and Sunspray oil. In multiple-choice treatment tests, numbers of adults found on the leaves at 2 and 4 h were not significantly different from the water control. After 24 h, bifenthrin and Sunspray oil-treated leaves had the fewest adults for up to 7 d, whereas M-Pede, *N. gossei* and Garlic Barrier showed no repellent effect on whiteflies. Leaves treated with bifenthrin and Sunspray oil had the fewest eggs. Fewer adults were found on the bifenthrin and Sunspray oil treated leaves through 24 h than all other treatments. Adult numbers on leaves treated with M-Pede, *N. gossei* extract and Garlic Barrier were not significantly different from the water treatment at 30 minutes.

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DATES COVERED BY REPORT: 1991-1993

PRINCIPLES FOR THE USE OF IMIDACLOPRID (ADMIRE®) FOR SILVERLEAF WHITEFLY CONTROL

Imidacloprid (Code Name - NTN 33893, Trade Name - Admire) has been tested as both a soil applied systemic and a foliar product for silverleaf whitefly control in field and vegetable crops beginning in 1991. Presented here are basic principles of imidacloprid use for whitefly control based on in-house and university/USDA cooperative research efforts. Soil applications, where feasible, appear to provide the most effective whitefly control, particularly when protection from virus transmission is a concern. Soil applications generally provide between 6-10 weeks of protection depending upon the application rate. Soil application rates developed for vegetables range between 0.15 - 0.5 lb ai/A depending on the crop and residual activity needed. Because soil mobility of imidacloprid is limited, the soil application must be made at or very near the root development zone to insure adequate uptake. The use of soil applied imidacloprid under medium-heavy whitefly pressure has resulted in earlier and more uniform harvests compared to standard product foliar programs.

When the soil application method is not feasible, imidacloprid is active on the whitefly as a foliar application. Effective foliar rates range between 0.05 - 0.125 lb ai/A depending upon spray interval required and crop phenology characteristics. Foliar applications of imidacloprid are not effective in controlling existing heavy infestations of whitefly. Foliar applications are effective if applications are initiated before the whitefly populations begin their exponential increases, and continued on a 5-10 day schedule. Activity from foliar applications appears to derive more from the ingestion of the material rather than through contact activity. Foliar applications also appear to be less efficacious if the leaves of the plant become "hardened off". It is postulated that this "hardening off" impedes the movement of imidacloprid into leaf tissue and is therefore less available to ingestion by the whitefly. In some cases, the addition of silicon-based surfactants enhances the activity of imidacloprid foliar sprays.

Laboratory studies with aphids, leafhoppers and preliminary studies with Colorado potato beetles and whiteflies suggest that imidacloprid with its novel mode of action, is not a high risk compound for rapid resistance development. However, extensive use of any single mode of action puts that chemistry in jeopardy relative to resistance development. Consequently, the use of this product within sound resistance management practices will be encouraged for all crop uses.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: March through June 1992.

CONTROL OF SILVERLEAF WHITEFLY ON CANTALOUPE MELON USING VARIOUS INSECTICIDES, SPRING, 1992.

A stand of cantaloupe melon (variety Topmark) was established on the University of California Desert Research and Extension Center March 26, 1992, using furrow irrigation. Nine insecticides treatments and an untreated control were evaluated for efficacy against the silverleaf whitefly. The treatments were Admire 240FS applied as a 2 inch band over the seedline March 25, 1992 at 0.13 lb(ai)/ac, followed by Admire foliar sprays tank mixed with M-Pede® at rates of 0.09 lb(ai)/ac and 1% by volume, respectively, applied on May 19, 27, June 3 and 10, 1992. All other treatments were foliar sprays of Thiodan® 3EC at 1.0 lb(ai)/ac, Applaud® 40SC at 0.38 lb(ai)/ac, Mitac® 1.5EC at 0.25 lb(ai)ac, Fenoxycarb 25WP at 0.25 lb(ai)/a, Applaud® 40SC tank mixed with Thiodan® 3EC at 0.38 lb(ai)/ac and 1.0 lb(ai)/ac, Mitac® 1.5EC tank mixed with Capture® 2EC at 0.25 lb(ai)ac and 0.1 lb(ai)/ac, Mitac® 1.5EC tank mixed with Thiodan® 3EC at 0.25 lb(ai)ac and 1.0 lb(ai)/ac, and Applaud® 40SC tank mixed with Mitac® 1.5EC at 0.38 lb(ai)/a and 0.25 lb(ai)/ac, respectively. Treatments were applied April 22, 29, May 6, 13, 19, 27, June 3 and June 10, 1992. Treatments were applied using a hand held CO_2 propelled spray using a 54 inch boom with 3 TXVS6 hollow cone nozzles with 18 inch spacing delivering 57.5 gpa at 30 psi. Nozzles at the ends of the boom were extended down 18 inches and angled in toward the crop canopy at 90°.

Adult whiteflies were counted on the second leaf from the terminal April 28, May 5 and 8, 1992, from 5 plants at random in each plot. Whitefly eggs, crawlers, nymphs (2nd and 3rd instars) redeyed nymphs (4th instars) and empty nymphal cases were counted on 2 (1.25 cm_2 discs from the lst true leaf April 30, 2nd true leaf May 5, 3rd true leaf May 12, 5th true leaf May 18, 6th true leaf May 28, 10th true leaf June 2, 11th true leaf June 9, and 12th true leaf June 16, 1992, on 5 leaves per plot at random. The most efficacious treatments for whitefly control were Admire® at planting over treated with Admire + M-Pede® foliar sprays, Thiodan® + Mitac®, Applaud® + Mitac®, Mitac® + Capture®, and Thiodan® + Applaud®. Fenoxycarb, Thiodan® and Mitac® used alone were not as efficacious as the tank mixtures listed above, but did provide some whitefly control.

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DATES COVERED BY REPORT: March through June 1992

SILVERLEAF WHITEFLY CONTROL ON MELONS USING VARIOUS INSECTICIDES, SPRING, 1992.

A stand of cantaloupe melon (variety Topmark) was established on the University of California Desert Research and Extension Center near Holtville, California March 13, 1992 using furrow irrigation. Nine insecticide treatments and an untreated control were evaluated for efficacy against the silverleaf whitefly. The experimental design was a randomized complete block with 4 replications. Admire® 240 FS was applied at a rate of 0.13 lb(ai)/a as a drench over the seedline prior to irrigation for germination March 13, using an 8004E flat fan nozzle applying 9.2 gpa at 36 psi in a 2 inch band. Foliar sprays of other insecticide treatments were applied with a hand held sprayer with 3-T XVS6 hollow cone nozzles delivering 57.6 gpa at 30 psi. Foliar sprays were applied March 21, May 6, 13 and 19, 1992. Foliar sprays included: Thiodan® 3EC 1.0 lb(ai)/a, Jojoba wax at 1%, Admire® 240 FS 0.09 lb(ai)/a+ M-Pede® at 1%, Rodspray oil at 10%, Aliette® 80WDG at 4.0 lb(ai)/a, M-Pede® at 1%, Capture® 2EC at 0.1 lb(ai)/a + Thiodan® 3EC at 1.0 lb(ai)/a, and Capture® 2EC at 0.1 lb(ai)/a.

Adult whiteflies were counted on the second leaf from the terminal April 27, 28, and May 8, from 5 plants at random from each plot. Whitefly eggs, crawlers, nymphs (2nd and 3rd instars) and redeyed nymphs (4th instars), were counted on 2 (1.25 cm^2) discs from the 2nd true leaf April 27, the 3rd true leaf May 12, the 5th true leaf May 18 and the 7th true leaf May 29 from 5 plants at random for each plot.

The Admire® at planting treatment, Admire®+ M-Pede®, and Capture®+ Thiodan® treatments had the lowest means for eggs and nymphs followed by Thiodan®, Rodspray and Jojoba wax. The Aliette®, Capture® and M-Pede® treatments were not greatly different from the untreated control.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: September 1992 through March 1993.

SILVERLEAF WHITEFLY CONTROL ON BROCCOLI USING VARIOUS INSECTICIDE, OIL, SOAP AND INSECT GROWTH REGULATOR TREATMENTS

A stand of broccoli: (variety: Packman) was established on the University of California Desert Research and Extension Center near Holtville, California September 16, 1992. Treatments included: an untreated control, Admire 0.23 lb(ai)/a at planting followed by foliar sprays of Admire® 0.021 lb(ai)/a + Monitor® 4 0.5 lb(ai)/a, Admire® 0.043 lb(ai)/a foliar, Lorsban® 50W 1.0 lb(ai)/a + Thiodan® 3EC 1.0 lb(ai)/a, Rodspray oil at 10%, JMS Stylet oil at 1%, Agro K Super Insecticidal Soap at 12.5%, Capture® 2EC 0.1 lb(ai)/a + Thiodan® 3EC 1.0 lb(ai)/a, Capture® 2EC 0.06 lb(ai)/a + Thiodan® 3EC 0.5 lb(ai)/a, Asana® 0.66 EC 0.05 lb(ai)/a, Lannate® L 0.75 lb(ai)/a, Asana® 0.66 EC 0.05 lb(ai)/a + Lannate® L 0.75 lb(ai)/a, Admire® 0.23 lb(ai)/a at planting followed by foliar sprays of Fenoxycarb 25W 0.25 lb(ai)/a, and Applaud® 40SC 0.038 lb(ai)/a alternating with sprays of Admire® 240FS 0.043 lb(ai)/a. At planting treatments were applied in a 1" band over the seedline September 15, 1992 using 36 gpa and 30 psi with a 8002 flat fan nozzle. Soap, wax and oils were applied October 8, 12, 15, 26, 30, November 2, 5, and 9, 1992. JMS Stylet Oil was sprayed two additional dates November 30 and December 3, 1992. Foliar sprays were applied using a tractor mounted sprayer with 3 Albuz lilac hollow cone nozzles per seedline using 425 psi and 51.78 gpa.

Insecticides were applied as foliar sprays October 8, 12, 19, November 2, and 5, 1992, with the exception of NTN33893 alternating with Applaud and Fenoxycarb following an NTN33893 at planting treatment. Applaud was applied October 8, 19 and November 5 and alternately NTN33893 was applied October 8, 19 and November 5 and alternately NTN33893 was applied October 15, and November 2, 1992. Fenoxycarb® was applied October 19, November 2 and 5, 1992.

Silverleaf whitefly eggs and nymphs were counted on basal leaves from five plants per plot within adisc of 1.25 cm^2 per leaf. Leaf samples were extracted October 13, 20, 27, November 3, 9, 16, 23, 30, and December 7, 1992.

The lowest nymph means were from treatments of Capture® + Thiodan® at both the high and low rates, Lorsban® + Asana®, Lorsban® + Thiodan®, Lannate® + Asana®, and Admire® at planting followed by foliar sprays of Admire® + Monitor®. With the exception of the control, Lannate®, AgroK, and JMS Stylet Oil had the greatest means for nymphs. There were no significant differences for yield means among treatments, but the Admire® at planting treatments reached maturity one month prior to any other treatments and five weeks prior to Applaud® alternating with Admire® as a foliar, AgroK, JMS Stylet Oil and the untreated control.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: March through September 1992

SILVERLEAF WHITEFLY CONTROL IN COTTON USING SYSTEMIC INSECTICIDES

Research plots were established on an April 2, 1993 planting of cotton (variety Delta Pine 5461) at the University of California Desert Research and Extension Center. Furrow irrigation was applied April 6, to germinate the cotton seed. The experimental design was randomized complete block with six treatments and five replications. Plots measured 26.67 feet by 45 feet which included eight rows of 40 inch spacing.

The treatments included: an untreated control, Temik® 15G (aldicarb) applied at 0.75 pounds active ingredient per acre in furrow at planting followed by Temik® 15G applied side-dress injected June 17 during first-bloom, three Gaucho® (imidacloprid) seed treatments of 8 ounces, 10 ounces and 12 ounces of active ingredient per hundred weight of seed, and Fenoxycarb insect growth regulator as a foliar spray applied at 0.25 pounds active ingredient per acre June 22 followed by foliar sprays of CGA215944 at 0.25 pounds active ingredient per acre applied June 23, July 5, July 14, July 28, and August 11.

Adult silverleaf whitefly were counted on five plants per plot May 25, and were again counted on one leaf from ten plants per plot June 18. Counts of silverleaf whitefly nymphs were from two discs of 1.25 cm^2 per leaf on five leaves per plot. Leaves were extracted from the first true leaf position May 26, eighth main stem leaf from the terminus June 16 and June 30, the sixth mainstem leaf from the terminus July 8 and July 19, and the fourth main stem leaf from the terminus July 29, August 4, August 10 and August 16. Each plot was harvested September 13, using a commercial picker and yield is reported as pounds of seed cotton per plot. There were no significant differences among whitefly adult means. The means for whitefly nymphs were not significantly higher than the control for Temik® 15G and Gaucho® seed treatments and on sampling dates from June 16 through August 26, although they exceeded the untreated control. The nymph means for CGA215944 were consistently lower than the untreated control from June 16 through August 16, but the means were not significantly different from the control. CGA215944 produced a mean seed cotton yield of 25.5 pounds per plot which was significantly, $P = 0.05$, greater than all other treatments. The control produced a seed cotton mean of 9.1 pounds which was significantly greater than Temik® 15G at 2.8 pounds. The Gaucho® seed treatments produced seed cotton means of 5.8, 7.9, and 3.2 pounds for the 12 oz, 10 oz and 8 oz cwt of seed rates, respectively, but these means were not significantly different from Temik® 15G or the control.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: March through July 1993

SILVERLEAF WHITEFLY CONTROL IN SPRING PLANTED CANTALOUPE MELONS, IMPERIAL COUNTY, CALIFORNIA, 1993

A stand of cantaloupe melons, variety Top Score, was established at the University of California Desert Research and Extension Center, Holtville, California March 16, 1993. Plots for five insecticide treatments and an untreated control were arranged in a randomized complete block design with five replications. The insecticide treatments were Applaud® 40SC at 0.25 lb(ai)/acre, Applaud® 40SC at 0.38 lb(ai)/acre, Thiodan® 3EC at 1.0 lb(ai)/acre, Applaud® 40SC tank mixed with Thiodan® 3EC at 0.25 lb(ai)/acre and 1.0 lb(ai)/acre, respectively, and Capture® 2EC tank mixed with Thiodan® 3EC at 0.1 lb(ai)acre and 1.0 lb(ai)acre, respectively. Insecticide spray was 22.1 gpa using a tractor mounted high pressure (400 psi) hydraulic sprayer. Four Albuz lilac hollow cone nozzles were arranged one foot over the crop canopy spaced 20 inches apart with the outer nozzles angled inward at 45° angles.

A pre-treatment sample of silverleaf whitefly adults, eggs, crawlers, 2nd and 3rd instar nymphs, redeyed nymphs and empty nymphal cases was collected May 3, 1993. Adults were counted on five random plants per plot as numbers of adults per plant for each treatment. Whitefly egg and nymph data were collected from leaves extracted from five plants per plot at random on May 3 (lst true leaf), May 20 (2nd true leaf), May 31 (4th true leaf), June 7 (4th true leaf), June 14 (4th true leaf), June 21 (12th true leaf), and June 25 (8th true leaf from cane terminus). Two leaf discs of 1.25 cm^2 were cut between the mid-rib vein and adjacent veins near the base of each leaf and whitefly immatures were counted and recorded for each sample.

Yield data of cantaloupe melons per 0.004 acres per plot were collected as number of melons per size category and total weight in pounds from a combination of all sizes of fruits. There were no significant differences among means for adult or immature whitefly from the May 3, pre-treatment counts. Applaud® + Thiodan® provided the lowest nymph counts through out the study followed by Applaud® at 0.38 lb(ai) acre, Applaud® at 0.25 lb(ai)/acre Capture® + Thiodan®, Thiodan® and the untreated control. Egg and crawler means for Applaud® treatments exceeded the means for the untreated control on June 21 and 25 and the control means for eggs and crawlers was lower than all insecticide treatments June 25. Means in the control plots were badly damaged from whitefly feeding late in the study and were not attractive to immigrating whitefly adults. Yield of all melon sizes was greatest for Applaud® at 0.38 lb(ai)/acre with a mean of 37.8 melons per plot which was significantly greater than the control at 9.8 and Thiodan® 23.2. There were no significant differences among the remaining means for melon fruit, but all insecticide treatments produced fruit yields significantly greater than the control.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: March through May 1992

CONTROL OF SILVERLEAF WHITEFLY IN FRESH MARKET TOMATOES USING VARIOUS INSECTICIDES, OILS, AN INSECT GROWTH REGULATOR, AND AN INSECTICIDAL SOAP

A stand of fresh market tomato (variety: celebrity) was established by transplanting March 13, 1993 at the University of California Desert Research and Extension Center. Sprinklers were used to establish the stand followed by furrow irrigation for stand maintenance. Thirteen insecticidal treatments were applied as follows: PFR (*Paecilomyces fumosoroseus*) from prills was applied to transplants as a dip 1 x 10^{10} spores/liter and followed by PFR-Oil MB3 sprays of 3.9 fl. oz. formulated product per acre; NTN33893 240-FS was applied as a soil drench at transplanting at 0.13 lb(ai)/acre in a four inch band using an 8004E flat fan nozzle at 30 psi delivering 17 gpa; NTN33893 240FS was applied as a foliar spray at 0.09 lb(ai)/acre; tank mixed with M-Pede® applied at 1 percent by volume; Danitol® 2.4EC at 0.2 lb(ai)/acre, foliar; Danitol® 2.4EC tank mixed with Monitor® 4 at 0.2 lb(ai)/acre and 0.75 lb(ai)/acre, foliar; Margosan-0 at 0.044 lb(ai)/acre, foliar; Fenoxycarb® 25WP at 0.25 lb(ai)/acre, foliar; Capture 2EC at 0.1 lb(ai)/acre, foliar; Capture® tank mixed with Monitor®4 at 0.08 lb(ai)/acre and 0.75 lb(ai)/acre, foliar; Monitor® 4 at 0.75 lb(ai)/acre, foliar; Capture® 2EC tank mixed with Thiodan® 3EC at 0.1 lb(ai)acre and 1.0 lb(ai)/acre, foliar; Thiodan® 3EC at 1.0 lb(ai)/acre; and Jojoba oil applied at one percent by volume. Foliar sprays were applied using a hand held CO^2 propelled sprayer. The boom measured 54 inches with three TXVS6 hollow cone nozzles with 18 inch spacing delivering 57.5 gpa at 30 psi. Nozzles at the ends of the boom were extended down 18 inches and angled in toward the crop canopy at 90°. Foliar sprays were applied April 27, May 4 and May 11, 1992.

Silverleaf whitefly eggs and nymphs were counted on 5 basal leaves per plot using a binocular microscope from samples extracted May 1, 8 and 18, 1992. NTN33893 240FS at 0.13 in furrow at planting provided the lowest seasonal mean for immature whitefly 2.92 per leaf, followed by Capture® + Thiodan® with 3.02 per leaf. NTN33893 + M-Pede® and Danitol® + Monitor® also provided high levels of whitefly control. All other treatments were not greatly different from the untreated control except Monitor which had a significantly greater, ($P = 0.05$). Number of silverleaf whitefly immatures than the untreated control and all other insecticide treatments.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: April through September 1993

SILVERLEAF WHITEFLY CONTROL IN COTTON USING INSECTICIDES AND AN INSECT GROWTH REGULAR

The silverleaf whitefly, *Bemisia* n. sp., infested vegetable crops in the Imperial Valley of California during the fall of 1990. Silverleaf whitefly overwintered on cole crops, weeds and ornamental plants to infest spring melons. The whitefly adults migrated from spring melons to cotton and from cotton to fall plantings of vegetable crops. This cycle has continued to cause economic losses to cotton growers as well as losses to vegetable and alfalfa growers. Cultural practices and biological control agents, parasitoids and predators of whitefly, have not eliminated the economic losses, nor are whitefly resistant cultivars available to prevent losses. Twelve insecticide products were used alone or in combination and an insect growth regulator was used for control of whiteflies for a total of 16 treatments including the untreated control. The highest levels of silverleaf whitefly control and greatest yields were obtained from Orthene® 90S at 0.5 pounds active ingredient per acre tank mixed with Danitol® 2.4 EC at 0.2 pounds active ingredient per acre and the Valent® insect growth regulator S-71639 at 0.07 pounds active ingredient per acre. The next highest yields and whitefly control were from S-71639 at 0.04 pounds active ingredient per acre, Mustang® 1.5E plus Orthene® 90S at 0.04 and 0.5 pounds active ingredient per acre, Baythroid® 2EC plus Monitor® 4 at 0.05 and 0.5 pounds active ingredient per acre, Asana® XL plus Thiodan® 3EC at 0.05 and 1.0 pounds active ingredient per acre and Capture® 2EC at 0.08 pounds active ingredient per acre. Asana® XL plus Vydate® L at 0.05 and 0.75 pounds active ingredient per acre, Penncap-M® plus Asana XL at 0.5 and 0.05 pounds active ingredient per acre, and Asana® XL plus Orthene® 90S at 0.05 and 0.5 pounds active ingredient per acre were less efficacious for whitefly control. AC303, 630 plus Capture® 2EC at 0.2 and 0.08 pounds active ingredient per acre, AC303, 630 at 0.4 pounds active ingredient per acre, BAS 300 1lI at 0.5 and 0.3 pounds of active ingredient per acre, and Penncap-M® plus Pounce® 3.2EC at 0.5 and 0.2 pounds active ingredient per acre were the least efficacious compared to the control.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: September 1992 through March 1993

EVALUATION OF FLOATING ROWCOVER MATERIALS TO EXCLUDE SILVERLEAF WHITEFLY FROM ICEBERG HEAD LETTUCE

Six rowcover materials, (Plastitech®, Agribond®, Vispore® X-6576, Vispore X-6577, Vispore X-6578, and Vispore X-6579) were placed over lettuce beds following direct seeding and were compared to untreated bare bed control plots open to silverleaf whitefly infestation, direct seeded September 25, 1992.

Each of the rowcover materials used in the experiment were very effective in excluding silverleaf whitefly adults. There were major problems associated with use of the covers. Weed control was not adequate to prevent competition with the crop. Additional labor costs and a risk of whitefly infestation could prohibit lifting the rowcovers for weed control. Reduced light under rowcovers may also prohibit their use on iceberg lettuce. Lettuce plants were etiolated and sensitive to sunburn upon removal of rowcovers.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: September 1992 through March 1993

EVALUATION OF INSECTICIDES FOR CONTROL OF SILVERLEAF WHITEFLY ON ICEBERG HEAD LETTUCE IN SOUTHERN CALIFORNIA

Several insecticides and oils included in the research project look promising for control of silverleaf whitefly in iceberg lettuce. Certain insecticides, such as Confidor 240FS, and oils could be compatible with biological control agents such as the parasitic wasps and predaceous beetles currently being investigated for control of silverleaf whitefly.

Based on the results of nymphal means in this insecticide efficacy trial the greatest level of sweetpotato whitefly control was obtained from Capture® 2EC plus Thiodan® 3EC at 0.1 and 1.0 lb(ai)/a followed by Asana® XL plus Lannate® L at 0.05 and 0.75 lb(ai)/a and Rodspray, followed by Jojoba wax 1% and Asana® XL at 0.5 lb(ai)/a followed by JMS Stylet oil 1%, Admire® 240 FS at 0.043 lb(ai)/a as a foliar alone, Admire® 240FS at 0.23 lb(ai)/a at planting followed by Margosan® O at 0.11 lb(ai)/a foliar, and Fury® 1.5 E plus Orthene® 75S at, and finally Admire® 240 FS 0.23 lb(ai)/a planting followed by foliar sprays of Admire® 240 FS at 0.021 lb(ai)/a plus Monitor® 4 at 0.5 lb(ai)/a. Lorsban® 50W at 0.75 lb(ai)/a, Agro® K super insecticidal soap 12.5% and Lorsban® 50W at 0.75 lb(ai)/a plus Monitor®. Lannate® L at 0.75 lb(ai)/a and Lorsban® 50W at 1.0 lb(ai/a were not efficacious as compared to the untreated control.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: 1993

NICOTINE DOES NOT ENHANCE ACTIVITY OF SUCROSE ESTERS FROM *NICOTIANA GOSSEI* AGAINST WHITEFLY NYMPHS

Nicotine is present in high abundance relative to other secondary metabolites in polar extracts from leaves of *N. gossei*. A test was conducted to determine if the presence of this toxic alkaloid would enhance the biological activity of sucrose esters with known insecticidal activity.

Bioassay consisted of two temporally replicated topical applications of aqueous solutions containing a total of 0.25-2.0 mg/ml of the chromatographically purified mixture of four sucrose esters obtained from *N. gossei* leaf surfaces, nicotine or a combination of both and a water control. Concentrations of nicotine alone or in combinations were 0.5 and 1.0 (0.1%) mg/ml; similarly, concentrations of the sucrose esters were 0.25-0.50 and 1.0 mg/ml. Treatments were applied to cohorts of second and third instar nymphs of *Trialeurodes vaporariorum* (Westwood) on tomato.

Nicotine alone at 0.5 and 1.0 mg/ml produced an average of 26 and 74% mortality, respectively. Combinations of nicotine and the sucrose esters produced on average, lower mortalities than the sucrose esters alone at 1.0 mg/ml (84%). Previous tests indicate that bioassay results on the greenhouse whitefly are transferrable to the sweetpotato whitefly, *Bemisia tabaci* (Gennadius).

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: September -December 1993

EVALUATION OF ADMIRE FOR CONTROL OF SWEETPOTATO WHITEFLY IN COMMERCIAL HEAD LETTUCE IN ARIZONA

Admire 2F was granted a Section 18 emergency exemption for use in head lettuce and cole crops for control of whiteflies in Arizona in August 1993. As a result, vegetable growers in Arizona used this material on several thousand acres. The Arizona Iceberg Lettuce Research Council provided funding in 1993 for field trials in the Yuma area to assess the performance of Admire under commercial growing conditions. Seven, 20-acre fields were direct seeded within a 2 day period with 'desert queen' lettuce. The fields were separated from each other by a minimum of 1/4 mile and no greater than 3 miles. Each field was treated with Admire at a rate of 16 fl. oz of Admire/acre in 3 gpa of water. The Admire was injected 3 inches below the seed line just prior to planting, and irrigated with overhead sprinklers immediately following planting. In each field, a control plot was established by leaving 4 rows, 150 feet in length untreated. Admire (treated) plots of equal size were established in each field adjacent to the untreated control plots. Whitefly populations were estimated weekly by removing 10 plants per plot and counting the total number of eggs and immatures whiteflies. Data was pooled across the seven paired plots for statistical analysis.

Populations of whiteflies in the test area were very high, with migratory populations active from plant emergence through heading. In general, untreated plots contained significantly greater numbers of eggs and nymphs than did Admire plots throughout the season. Colonization was significantly reduced in Admire plots as indicated by low incidence of eclosed pupal cases. Differences in plant vigor and growth were observed at various times in the season. At the plant thinning and heading stages of growth, dry weights for plants treated with Admire were greater than untreated plants. At harvest, a significant yield response was observed in plots treated with Admire. Quality, size and color were considered good in the Admire plots. However, plants in the untreated plots were pale yellow, and head weight and head size were reduced 27 and 21 % respectively. Overall, Admire appeared to provide good control of sweetpotato whitefly throughout the Yuma area.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: February-June 1993

INSECTICIDAL CONTROL OF SWEETPOTATO WHITEFLY ON SPRING MELONS

Evaluation of several experimental compounds for control of sweetpotato whitefly (SPWF), *Bemisia tabaci* on spring cantaloupes was conducted in the Yuma Valley of Arizona in 1993. The following treatments were evaluated in a full-season test: 1) Admire 2 FS at 0.25 lb ai/acre; 2) CGA 215944 WP at 0.25 lbs ai/acre; 3) Fenoxycarb WP at 0.25 lbs ai/acre; 4) Applaud SC at 0.38 lbs ai/acre; 5) Applaud SC at 0.25 lbs ai/acre; 6) Applaud WP at 0.25 lbs ai/acre; 7) Applaud SC 0.25 + Thiodan 3EC at 1.0 lbs ai/acre; 8) Thiodan 3EC at 1.0 lbs ai/acre; 9) Capture 2E at 0.08 + Thiodan at 1.0 lbs ai/acre; 10) an untreated control. Admire was applied as a soil drench to individual plants at thinning. Weekly foliar applications in treatments 2-9 were initiated when immature whiteflies reached a density of 5 nymphs per leaf. A total of 5 sprays were applied. Foliar sprays were applied using a high-pressure, electrostatic sprayer equipped with stainless steel, hollow-cone nozzles (TX-18) spaced at 20 in and calibrated to deliver 60 gpa at about 400 psi. SPWF immature densities were estimated weekly by counting total immatures (eggs, nymphs, and eclosed pupal cases) on cm^2 leaf disks taken from the undersides of leaves. Yield data was collected from each plot over a two week period.

Applications of Admire and Applaud maintained SPWF populations at very low densities relative to the untreated control. Colonization of immature populations, as measured by the incidence of eclosed pupal cases, was prevented in these plots. Colonization was low in plots treated with CGA 215944 and Capture+Thiodan, and immature populations were maintained at levels significantly lower than the control. Thiodan and Fenoxycarb did not provide significant control of SPWF, as colonization was high in these treatments. Yield data collected at the end of the study showed that the most efficacious treatments (Admire, Applaud, CGA 215944, and Capture+Thiodan) harvested more marketable melons than all other treatments. The Thiodan, Fenoxycarb, and untreated check plots experienced reductions in marketable fruit (20-50%), reductions in soluble sugars (2%), and excessive levels of honeydew contamination (15-45%).

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: January 1, 1993 - November 30, 1993

MONITORING AND MANAGEMENT OF INSECTICIDE RESISTANCE IN THE SWEETPOTATO WHITEFLY, *BEMISIA TABACI*

An insecticide-coated yellow sticky card technique was used to test for resistance to various chemicals in use against whiteflies. This technique was extended widely and used for continuous monitoring to a number of insecticides in Imperial, Palo Verde and San Joaquin valleys in California during 1993. A more up-to-date survey of the spectrum and regional variation of resistance has become necessary for continuous evaluation and management. More than 50,000 insects were tested during cotton, melon and vegetable growing seasons. The data show the changes in the presence or absence of resistance to bifenthrin and endosulfan in various locations. The data also represent baseline values for a few other chemicals which are effective against whiteflies.

As a means of combating resistance problems, various approaches to insecticide applications such as the use of unrelated compounds in rotations and mixtures have been tested in the greenhouse. Selection with insecticide mixtures and rotations resulted in the delay of resistance development for a few generations in *B. tabaci* adults compared with single continuous selection with bifenthrin or endosulfan. Data also show that bifenthrin resistance was overcome by endosulfan showing no cross-resistance between bifenthrin and endosulfan. Based on these results, the use of rotations and mixtures of insecticides in the field in order to delay development of resistance merits consideration.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: May 1993 - December 1993

INSECTICIDE CONTROL AND RESISTANCE MANAGEMENT IN WHITEFLY POPULATIONS

Greenhouse/cage tests are being conducted to isolate whitefly populations, expose them to specific insecticide treatment, and measure dose-mortality response over time to determine how long it takes to select for resistance. This test began in August 1993 and will be continued on cotton through May 1994. Once selection for resistance is accomplished, then various combination treatments will be evaluated for their ability to overcome resistance. A full-season melon test was conducted in the late summer of 1993 with the following per acre treatments: 1. Admire (NTN) 0.5 lb AI in furrow, 2. Admire (NTN) 0.044 lb AI + Silwet 8oz/100gal, 3. Tame 0.1 lb AI + Orthene 0.5 lb AI, 4. CGA 215944 40 g AI + Silwet 8oz/100gal, 5. CGA 215944 80 g AI + Silwet 8oz/100gal, 6. CGA 215944 80 g AI, 7. M-Pede 2% + Agrimek 0.02 lb AI, 8. Agrimek 0.02 lb AI, 9. M-Pede 2%, 10. Nicotiana x 1, 11. Nicotiana x 0.5, 12. Applaud 0.25 lb AI, 13. Applaud 0.38 lb AI, 14. Applaud 0.25 lb AI + Thiodan 1.0 lb AI followed by Thiodan 1.0 lb AI, 15. Thiodan 1.0 lb AI, 16. untreated, and results are forthcoming. Treatments being evaluated in greenhouse are as follows:

	AI/50 gal	bioassay (weekly)
(1) bifenthrin (2EC)	0.08	yes
(2) a rotation of bifenthrin and endosulfan (3EC)	0.08, 1.0	
(3) a mixture of bifenthrin and endosulfan	0.08, 1.0	
(4) a mixture of bifenthrin and acephate (90S)	0.08, 1.0	
(5) acephate	1.0	yes
(6) a mixture of bifenthrin and methamidophos (4)	0.08, 1.0	
(7) a mixture of cyfluthrin (2) plus methamidophos	0.05, 1.0	
(8) a mixture of fenpropathrin (2.4) plus acephate	0.2, 1.0	
(9) a pretreatment of fenoxycarb (25WP), bifenthrin	0.2, 0.08	
(10) endosulfan	1.0	yes
(11) a mixture of buprofezin (440F) and endosulfan	0.5, 1.0	
(12) amitraz (1.5EC)	0.25	yes
(13) imidacloprid (240S)	0.11	yes
(14) fenpropathrin	0.2	yes
(15) fenoxycarb	0.2	
(16) untreated check	none	

INVESTIGATOR'S NAME(S): Dale Schaal, President

AFFILIATION & LOCATION: Airtec Sprayers, Inc., Winter Haven, FL

RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: Sprayers in production since 1988

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INVESTIGATOR'S NAME(S): D. Seal, R. Baranowski, R. McMillan, Jr., & H. Bryan

AFFILIATION & LOCATION: Univ. of Florida, TREC, Homestead, FL. 33031

RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATES COVERED BY REPORT: Past season (1993)

MANAGEMENT OF WHITEFLY, BEMISIA TABACI (GENNADIUS) AND ITS ASSOCIATED SILVERLEAF DISORDER ON SQUASH

In the present study, different combinations of insecticides were used to control whitefly. Use of abamectin (0.01 kg/ha) in combination with pyrethrins (0.01 kg/ha)/rotenone (0.01 kg/ha) reduced whitefly numbers on beans after three applications at weekly intervals. Imidacloprid (0.04 kg/ha) applied once on soil at planting supressed whitefly populations for 8 weeks.

Although several insecticides reduced whitefly populations, it was difficult to control sweetpotato whitefly associated squash silverleaf disorder. In an effort to control squash silverleaf, insecticides were applied in squash using different methods. In the first study, application of imidacloprid (0.04 kg) at planting followed by weekly foliar application of imidacloprid at 0.04 kg/ha significantly ($P < 0.05$) reduced squash silverleaf disorder. The same treatment when used at biweekly and every 3 weeks did not reduce squash silverleaf. Numbers of leaves and canopy volume per plant did not differ among treatments.

In the second study, application of imidacloprid at 0.04 kg/ha on soil at planting followed by twice weekly foliar applications of imidacloprid at 0.02 kg/ha + mineral oil (4 kg/ha) for four weeks significantly reduced squash silverleaf. Other treatments (imidacloprid at 0.04 kg/ha on soil only at planting, imidacloprid sy 0.04 kg/ha on soil at planting followed by twice weekly application of mineral oil(4 kg/ha) did not differ from nontreated check in reducing squash silverleaf. None of the treatments showed any sign of phytotoxicity during this study

In the third study, Treatments evaluated were: (1) soil application of imidacloprid (0.04 kg/ha) at planting; (2) soil application of imidacloprid at 0.04 kg/ha at weekly intervals; (3) Treatment (1) + foliar application of imidacloprid at 0.02 kg/ha twice weekly; (4) Treatment (1) followed by soil and foliar application of imidacloprid at 0.02 kg/ha each; (5) foliar application of mineral oil (4 kg/ha) twice weekly; (6) combination of Treatments 3 and 5; (7) Treatment (1) followed by pyrethrins (0.01 kg/ha)/rotenone (0.01 kg/ha); and (8) a nontreated check. Only soil application of imidacloprid at 0.04 kg/ha at planting followed by twice weekly foliar applications of imidacloprid at 0.02 kg/ha + mineral oil for four weeks significantly reduced squash silverleaf when compared with nontreated check.

INVESTIGATOR'S NAME(S): R. F. Severson[1], M. G. Stephenson[2], O. T. Chortyk[1], B.W. Maw[3], J. W. Neal, Jr.[4], G. W. Pittarelli[4], J. G. Buta[4], D. M. Jackson[5], and A. W. Johnson[6].

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control,Biorationals, and Pesticide Application Technology.

DATES COVERED BY REPORT: January 1993 - October 1993

FIELD PRODUCTION OF *NICOTIANA* SPECIES

Objectives. Grow enough *N. gossei* and other *Nicotiana* species for the isolation of leaf surface chemistry for field screens of the SPW biorational sugar ester in late summer or fall.

N. gossei was grown on 2 1/2 acres at the Coastal Plain Experiment Station in Tifton GA and was harvested and washed in iso-propyl alcohol 5 times during the growing season. The resulting extract was then fractionated, solvent partitioned and the isolated biorational was sent to cooperators in AZ, FL, MD, CA, TX, SC, MS, GA, and NC for field testing against SPW.

Thirteen *Nicotiana* species (*N. pauciflora, N. glutinosa, N. trigonophylla, N. repanda, N.benthamiana, N. gossei, N. amplexicaulis N. palmeri, N. stocktonii, N. langsdorffii, N. cavicola, N. hesperis, N. simulans*) were grown in 300 plant plots in GA, SC, and NC. Sugar ester extracts will be fractionated and partitioned and isolates will be used for future testing against SPW.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

DATE COVERED BY REPORT: 1993.

B. TABACI CONTROL & TOMATO MOTTLE GEMINIVIRUS (TMoV) IN FL STAKED TOMATO

Detergents, oils and conventional insecticides were evaluated on field-grown staked 'Sunny' tomato for efficacy in controlling immature and adult sweetpotato whitefly *Bemisia tabaci* (Gennadius) and reducing the spread of tomato mottle geminivirus (TMoV). Experimental design was randomized complete block with 4 replications, each 3 rows wide by 240 ft long, divided into 1 0 plots for 9 treatments and an unsprayed check. Symptomatic greenhouse raised tomato plants, which had been exposed to TMoV-infected whitefly, were interplanted in the experimental blocks. An adjacent field of fall-planted collards provided additional whiteflies. At harvest, fruit was graded and a sampling of marketable tomatoes were evaluated for irregular harvesting.

Whitefly infestation was heavy during most of the trial and a strong block effect observed due to migration from infested collard field. Geminivirus infection spread rapidly through the plots from the planted sources. Differences between treatments were observed for all parameters. In general, pyrethroid+Monitor tank mixes performed best. Karate+Monitor was the best overall treatment, although not better than Asana or Ambush+Monitor on most sample dates. Stylet Oil performed as well or better than pyrethroids alone. Significantly fewer adults and immatures were found on plants treated with New Day detergent even though the concentration was very low (0.05%). Treatment effects on new TMoV infection were significant for only 3 of the 6 sample dates. Karate+Monitor had the lowest rates overall, although not significantly different from the majority of treatments. Numbers of pupae parasitized, principally by *Encarsia pergandiella*, reached 32% in the control plots and were observed in all treatments except Karate+Monitor. The lowest number and weight of marketable fruit occurred in the check, although not significantly less than from the Stylet Oil treatment. This was possibly due to phytotoxicity, in the form of leaf burn, which was observed on plants sprayed with Stylet Oil. New Day (0.5%) yielded significantly more marketable fruit than the check. Karate+Monitor sprayed plants yielded best, although not significantly better than Ambush+Monitor. Percent irregular ripening was high for all treatments, ranging from 94% (YE656 and Check) to 77-78% (Karate+Monitor, Asana+Monitor).

INVESTIGATOR'S NAME(S): Philip A. Stansly and Tong-Xian Liu

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

DATE COVERED BY REPORT: 1993.

BIOASSAYS OF BIORATIONAL INSECTICIDES FOR SWEETPOTATO WHITEFLY CONTROL

One of our objectives was to determine the potential for development of biorational insecticides for sweetpotato whitefly, *Bemisia tabaci* (Gennadius) management on vegetables.

Studies Completed:

Insecticides used in our laboratory included Sunspray Ultra-fine Oil, M-Pede (an insecticidal soap),*Nicotiana gossei* extract and bifenthrin (Brigade 10W) with water as a control. Tomato plants

(*Lycopersicum esculentum* Miller, 'Lanai') were potted singly in 9-15-cm plastic pots. *B. tabaci* were maintained in greenhouse for four years.

Repellency of these insecticides on *B. tabaci* has been evaluated under laboratory and greenhouse conditions in dual and multiple choice tests. Results indicated that whiteflies avoided the plants treated with bifenthrin, Sunspray oil, *N. gossei* extract and M-Pede, as indicated by fewer adults and eggs on the plants, than those treated with Garlic Barrier and water.

Leaf-dip bioassays for toxicity of these insecticides on *B. tabaci* adults, young nymphs (7 d old) and old nymphs (14 d old) were conducted in the laboratory. Bioassays with residues dried on leaves showed that Sunspray oil gave highest mortality to adults for up to 5 d after treatments. Dry residues of bifenthrin gave high mortality for up to 2 h only. M-Pede and *N. gossei* extract were not effective on adults. All insecticides tested were effective on young nymphs. Along with bifenthrin and Sunspray oil, M-Pede and *N. Gossei* extract were very effective on nymphs. Sunspray oil was the only one which gave 60% egg mortality at $\geq$ 1% rates.

Studies in progress:

Bioassays using sprayed tomato leaves will be evaluated and the results will be compared with leaf-dip bioassays.

Effect Of these insecticides to whitefly oviposition is in progress and will continue.

Effects of these insecticides on parasitoids, *Encarsia pergandiella, En. transyena* and *Eretmocerus* sp. will be determined under laboratory and greenhouse conditions.

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RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals and Pesticide Application Technology

DATE COVERED BY REPORT: October 1992 - September 1993

EVALUATION OF BROAD SPECTRUM VS. BIORATIONAL INSECTICIDES

Control of SLW in tomatoes was compared using a broad-spectrum 'hard' chemical (endosulfan) vs. a 'soft' chemical (M-Pede, a soap). Populations of SLW and three classes of beneficials (spiders, parasitoids, and *Orius*, a hemipterous predator) were monitored before and after treatment by means of D-vac suction sampler (100 sucks per treatment) at bi-weekly intervals for three weeks. SLW populations were reduced 66% by M-Pede and 80% by endosulfan. Spider populations were reduced 10% following M-Pede treatment and 47% by endosulfan; parasitoid wasps were reduced ca. 47% by both treatments; populations of *Orius* were not reduced by either treatment.

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AFFILIATION & LOCATION: USDA, ARS, Crop Insects Res. Lab, Weslaco, TX

RESEARCH & IMPLEMENTATION AREA: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

DATES COVERED BY REPORT: March through August 1993

FIELD AND GLASS VIAL BIOASSAYS OF INSECTICIDES AGAINST SWEETPOTATO WHITEFLY

Sprays (15) of endosulfan (0.56 and 1.12 kg (a.i.)/ha), bifenthrin, (0.09 kg (a.i.)/ha) bifenthrin + endosulfan (0.56 kg (a.i.)/ha), bifenthrin then endosulfan (0.56 kg (a.i.)/ha) were applied season long and percentage control of adults ranged from 53 to 100%. Adult populations in untreated plots ranged from 0.33 to 20.13 adults/leaf. Bifenthrin and endosulfan alone had the lowest percentage control but yields of treated plots were statistically equal to untreated plots. Control of immatures by these same treatments were equal to those obtained for adults.

Glass vial bioassays for bifenthrin and endosulfan were conducted in each of the treated plots and the check. There was no difference in LC_{50} values for either bifenthrin or for endosulfan in the untreated check. However certain LC_{50} values for the mixture and the alternate applications of the two insecticides were greater than the untreated check. Results do not indicate development of resistance to these insecticides during the 1993 season. Fipronil (0.084 kg (a.i.) and Ciba CGA 215944 and fenoxycarb at 0.28 kg (a.i.)/ha gave 80% to 95% control of adults and immatures of this insect.

TABLE C. Summary of Research Progress for Section C - Chemical Control, Biorationals and Pesticide Application Technology in Relation to Years 1 and 2 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
C.1 Identify for registration, new chemicals and formulations that effectively control SPW.	Yr. 2: Expand field research with best combinations and application methodology.	X		Continued progress was made in field evaluation of promising materials with activity against SLW. Cooperative research efforts led to the registration or the securing of section 18's allowing the use of Admire, Capture, and Danitol in several states.
C.2 Identify for registration, biorational materials with new modes of action.	Yr. 2: Conduct field studies to determine coverage, rates, gal/acre, etc., to provide data useful for registration purposes.	X		Further examination of plant derived oils, *Nicotiana* spp. extracts, neem and several soaps determined activity against immature SLW. Biorationals may be most efficacious in combination with insecticides or used in rotational systems.
C.3 Develop application schedules and methods in relation to economic thresholds.	Yr. 2: Determine relationship between SPW populations, chemical control, and yield for economic threshold.	X		Yield vs. Density relationships for SLW in cotton, melons, cole crops and lettuce have been initially established. Tentative economic and action thresholds have been proposed for field validation next season.
C.4 Insecticide resistance studies.	Yr. 2: Develop standardized insecticide resistance monitoring systems.	X		Standardized monitoring systems using an insecticide-coated sticky easel technique developed in California has been tested, and efforts to implement the monitoring system in other locations are being made.
C.5 Genetics of insecticide resistance in SPW.	Yr. 2: Begin construction of isogenic resistant and susceptible strains through back-crossing and selection.		X	No detailed studies have been conducted on genetics of insecticide resistance. Research in California has been initiated to start genetic analysis of resistance in SLW.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
C.6 Develop methods for application or delivery of materials to improve control.	Yr. 2: Evaluate modified spray equipment, boom drops, nozzles, and arrangements; and chemigation.	X		Further examination of application technology indicated that electrostatic and high air-volume ground sprayers gave no advantage over conventional sprayers for spray deposits on the undersides of leaves. Studies of aerial application showed that spray deposition on plant leaves can be affected by airspeed and nozzle types.
C.7 Evaluate application methodologies for impact on natural enemies and SPW interactions.	Yr. 2: Determine effect of various chemicals and biorationals on natural enemy populations and associated minor pests.	X		Studies were conducted in Florida, Texas and California examining the effects various chemicals on SLW natural enemies. Results indicated that parasitoids and predators responded differently to biorationals, IGRs and conventional insecticides.

RESEARCH SUMMARY

Section C: Chemical Control, Biorationals and Pesticide Application Technology

Compiled by

John C. Palumbo and Nick C. Toscano

C1. Identify for registration, new chemicals and formulations that effectively control silverleaf whitefly (SLW).

Cooperative research efforts in Arizona, California, Florida and Texas among ARS-USDA, University research and extension scientists led to the registration or the securing of section 18's allowing the use of new insecticides for the control of SLW. Among the most prominent materials obtained for grower use were Admire (imidacloprid), Capture (bifenthrin), and Danitol (fenopropathrin).

Work continued throughout SLW infected areas testing the efficacy of many materials against SLW. The following materials were tested for SLW control: Admire (imidacloprid), Thiodan (endosulfan), Ovasyn/Mitac (amitraz), Fenoxycarb, Applaud, (buprofezin), Capture (bifenthrin), Aliette (fosethyl), Lorsban (chlorpyrifos) Asana (esfenvalerate), Lannate (methomyl), Temik (aldicarb), Danitol (fenpropathrin), Monitor (methamidophos), Orthene (acephate), Vydate (oxamyl), Agri-Mek (abamectin) and Karate (lambda-cyhalothrin). The above materials were tested single, in combination or tank-mixed with a biorational material such as a soap, oil or botanicals margosan, rotenone, pyrethrins, neem extract/oil and Jojoba oil/wax.

All of the materials tested show various activity against SLW, but Admire, combinations of Danitol + Orthene and Capture + Thiodan showed the greatest activity against SLW.

C2. Identify for registration, biorational materials with new models of action.

Several studies were conducted investigating the activity of biorationals against whiteflies. Several plant derived oils, plant extracts, neem seed products and soap types were evaluated. Results suggest that soaps, oils and neem seed products, either alone or in combination, were capable of reducing SLW populations. Studies evaluating repellency of oils, soaps, and garlic barriers showed that SunSpray oil provided some repellency, but Garlic did not significantly repel adults. Studies have been initiated to use biorationals in full season rotational systems on cotton. Satisfactory control as indicated in the 1993 report can be limited by the method of application.

C3. Develop application schedules and methods in relation to economic thresholds.

Populations levels under various management systems are underway. SLW density relationships to crop yield have been initiated on cole crops, cotton, lettuce, tomatoes and melons. In 1994 provisional SLW thresholds will be identified on some crops.

C4. Resistance management studies are being conducted in California and Texas.

In California an insecticide-coated sticky easel technique was used to test resistance to various chemicals in use against SLW. More than 50,000 insects collected from cotton, melons and cole crop fields were tested for resistance in California. The data showed that there can be changes in the presence or absence of resistance to Capture (bifenthrin) and Thiodan (endosulfan) in various locations in California. In Texas the

"glass vial" bioassay using a dosage series of Capture and Thiodan was conducted to measure SLW mortality.

As a means of combating resistance problems, various approaches to insecticide applications such as the use of unrelated compounds in rotations and mixtures have been tested in the green house in California and Texas. Results in California showed a delay in SLW resistance development for a few generations in SLW adults when rotations and mixtures of insecticides were used when compared with continuous selection of Capture or Thiodan.

C5. Genetics of insecticide resistance in SLW.

No research progress was reported for detailed analysis of resistance. California has started a program to do genetic analysis of resistance in SLW.

C6. Develop methods for application or delivery of materials to improve control.

Progress to compare methods of ground and air application for estimation of underleaf coverage was significant. Ground application of insecticides in Arizona and California indicate that electrostatic and high air-volume sprayers give no advantage over conventional hydraulic sprayers for spray deposit on the undersides of leaves. Efficacy with insecticide combinations delivered with the electrostatic system was on occasion significantly greater than conventional hydraulic sprayers, but overall results were highly variable. Studies of aerial application showed that spray deposition on plant leaves can be affected by airspeed and nozzle types.

C7. Evaluate application methodologies for impact on natural enemies and SLW interactions.

Progress was made in studying the impact of chemical or biorational control on natural enemies complexes. One test in California indicated some natural enemies may have developed a tolerance for insecticides. Laboratory tests conducted in Texas indicated that some parasitoids were more tolerant to Buprofezin than conventional insecticides.

D. Biocontrol

Chairs: Lance Osborne and Lloyd Wendel

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: August - September, 1993

USE OF THE FUNGUS, *BEAUVERIA BASSIANA*, AS *NATURALIS L* AGAINST THE SWEETPOTATO WHITEFLY (SPWF), *BEMISIA TABACI* IN FURROW AND SUB-DRIP IRRIGATED COTTON

SUNDANCE FARMS of Coolidge, AZ was chosen for the primary study site and DPL 5415 cotton used. For the furrow irrigation test, a field was divided into two 15-acre halves. *B. bassiana* was applied to one half of the field (15 sub-sampling plots, 3 X 5 deep). The synthetic pyrethroids bifenthrin (as Capture) and zeta-cypermethrin (as Mustang) were applied to the second half (5 and 10 ac, subplots of 1 X 5 deep and 2 X 5 deep, respectively,) as a standard for comparison. For the sub-drip irrigated test, 2 fields were used. In field one, 15 ac were treated with *B. bassiana* and in the second field, bifenthrin was applied to 5 and zeta-cypermethrin to 10 ac. Subplot divisions were similar to the furrow irrigation test. Application rates were by label and at 25-30 gal/Ac applied with a ground sprayer (JD 6000 HI CYCLE) with inverted Y drops on the boom at 70-90 psi. Five applications were made by ground in August and September. All lifestages of SPWF were sampled.

For SPWF egg counts in drip irrigated cotton, mean number/cm^2 were 0.07, 0.04, and 0.10 for *B. bassiana*, bifenthrin, and zeta-cypermethrin, respectively; differences among means were not significant. For SPWF egg counts in furrow irrigated cotton, mean number/cm^2 were 4.60, 1.24, and 1.50 for *B. bassiana*, bifenthrin, and zeta-cypermethrin, respectively; differences between means for drip vs furrow irrigation were significant at $P < 0.05$. By 2-way ANOVA, the *B. bassiana* egg mean in furrow irrigation (4.60) was highly significant from all other means at $P < 0.001$ - interaction.

For SPWF large immature counts in drip irrigated cotton, mean number/cm^2 were 0.02, 0.03, and 0.04 for *B. bassiana*, bifenthrin, and zeta-cypermethrin, respectively; differences among means were not significant. For SPWF large immature counts in furrow irrigated cotton, mean number/cm^2 were 0.45, 0.40, and 0.45 for *B. bassiana*, bifenthrin, and zeta-cypermethrin, respectively; differences between means for drip vs furrow irrigation were significant at $P < 0.05$. There was no interaction.

For furrow irrigation, mean counts per cm^2 of large immatures at the end of the season were 6.6, 5.9, 6.9, and 5.9 for *B. bassiana*, bifenthrin, and zeta-cypermethrin, and a 'best agricultural practices field", respectively; differences among means were not significant. However, for an untreated field (received one insecticide treatment-late season) the mean was 41.3 and was significant from the other means at $P < 0.001$. The yields, in bales, for the treated fields were all > 2.8 and was < 2.1 for the untreated field; these differences were significant at $P < 0.05$. None of the cotton, neither leaves nor lint, showed signs of stickiness in treated plots. A small additional experiment was conducted at the USDA, ARS Western Cotton Research Laboratory, with DPL 5415 and furrow irrigation. A small split plot design (3 rows X 16 ft) with 5 plots and 4 replicates deep per treatment received three 5-7 day applications of *B. bassiana* for one treatment and the other was the control. This test was done in September to present a "worst case scenario" in terms of SPWF numbers. For *B. bassiana* treated plots, mean number of eggs/cm^2 were 39.11 versus 46.67 for the control plots; means were not significantly different. However, for the mean number of large immatures, 1.33 for *B. bassiana* treated plots and 3.64, the difference was highly significant at $P < 0.001$ and represented a percent reduction of 63%.

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RESEARCH & IMPLEMENTATION AREA: Section D, Biological Control

DATES COVERED BY REPORT: 1992-1993

PARASITISM OF SILVERLEAF WHITEFLY IN CALIFORNIA CROPS AND WEEDS

A survey of natural enemies indigenous to southern California attacking the silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring) was undertaken in concert with a survey of host plants for this whitefly. The survey demonstrated that in the desert communities, three parasitoids comprise almost the entire fauna. These were *Eretmocerus* sp. nr. *californicus*, *Encarsia luteola* Howard, and *Encarsia meritoria* Howard, with *Eretmocerus* sp. being the most common.

Among these three parasitoids, rates of parasitism varied greatly on different host plants. Some plants had almost no parasitism, while other plants had parasitism reaching 90%. Reasons for these differences may include host plant morphology, host plant chemistry, or other effects. We have initiated a set of behavioral studies to determine if there are host plant characteristics that may explain different patterns of parasitism on different host plant species.

The survey of parasitoids has indicated a depauperate fauna compared to other regions of the world, suggesting that introductions of natural enemies other than those present may prove beneficial. The initial studies of plant effects on extant natural enemies will lead to an understanding of what traits may be associated with successful parasitism.

New natural enemies of *Bemisia argentifolii* were imported from southeastern North America into quarantine at Riverside. These include several species of *Encarsia*. *Amitus* sp. from Central America also was imported from Florida. Quarantine studies are under way for the imported *Amitus* sp. and *Encarsia* species prior to release.

The introduced predatory coccinellid *Serangium parcesetosum* was introduced into urban settings against *B. argentifolii*, where it reproduced successfully. Its potential impact on the whitefly has not been evaluated.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 92 - 93.

FIELD EVALUATIONS OF *DELPHASTUS PUSILLUS* FOR CONTROL OF *BEMISIA TABACI* INFESTING UPLAND COTTON

The coccinellid beetle, *Delphastus pusillus*, was evaluated for control of *Bemisia tabaci* infesting cotton in the Imperial Valley over two field seasons. Eight one half acre experimental plots were utilized for this study. *D. pusillus* releases were made both, in the open field and in whitefly exclusion cages, which provided four treatments and four replicates of each treatment. Releases for the length of the study totaled 4 beetles/plant in 1992 and 5 beetles/plant in 1993. The effects of each treatment were evaluated utilizing a stratified random leaf sample taken at weekly intervals. The number of whiteflies, parasitized whitefly nymphs, and *D. pusillus* observed within a specific leaf area ($2cm^2$) were determined from these samples. Results obtained from the open field show no significant difference in the whitefly densities between release and non-release treatments, both in 1992 and in 1993. The cage treatments, which eliminate the effects of whitefly migration, revealed whitefly densities in the beetle release cages 33% of the densities observed in the non-release cages. These results were expected in that heavy whitefly migration into the fields was observed throughout the study via yellow sticky cards (100 whitefly adults/12 in^2/24 hours). Parasitoids in the genera *Encarsia* and *Eretmocerus* were observed parasitizing whitefly nymphs with no significant reduction in their populations due to the feeding of *D. pusillus*. The results obtained by this study suggest compatibility between *D. pusillus* and endemic parasitoids, which is consistent with laboratory and greenhouse studies conducted at U.C. Davis. However, the astronomic populations and heavy whitefly migration observed in the Imperial Valley resulted in little success of control.

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RESEARCH & IMPLEMENTATION AREA: Section D: BioControl

DATES COVERED BY REPORT: Nov. 1992 - Nov. 1993

DEVELOPMENT OF FUNGAL PATHOGENS FOR CONTROL OF SWEETPOTATO WHITEFLY

Under a Cooperative Research and Development Agreement, we are investigating the potential of several hyphomycete pathogens as whitefly biocontrol agents within frameworks of both conventional microbial control and novel augmentative control strategies. Laboratory assays have identified strains of *Paecilomyces fumosoroseus* and *Beauveria bassiana* as the most promising control candidates (the most virulent isolates exhibit LC50s of approx. 50-100 conidia/mm^2 against third-instar whiteflies). *P. fumosoroseus* is the most frequently isolated natural pathogen of *B. tabaci* in the U. S., commonly causing epizootics under greenhouse conditions in Florida and Texas and interfering with whitefly colony maintenance. In southern Texas, epizootics have also been observed in open field situations; in a fall broccoli planting surveyed during November 1992, point infection levels reached approximately 30 and 60% in nymphal and adult populations, respectively. *B. bassiana*, while not an important naturally occurring pathogen of whiteflies, is currently being developed as an insect control agent in the U. S. and has been used on large scales in other countries for microbial control of various agricultural pests. Initial field trials with *P. fumosoroseus* and *B. bassiana* are in progress at SARL. Single applications of 1e13 to 5e13 conidia per acre have produced 20 - 70% infection of whitefly nymphs on fall-planted broccoli. Trials of various formulations have shown these two pathogens to be equally efficacious. Characteristics such as mass-culture capacity, shelf-life, and safety to nontarget organisms also are under investigation, and results will ultimately identify strains for commercial product development.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: June 1 through September 1, 1993

A SERIOLOGICAL ANALYSIS OF PREDATORS OF THE SWEETPOTATO WHITEFLY EGG STAGE

We examined the gut contents of over 10,000 predators collected from Arizona cotton fields for the presence of sweetpotato whitefly egg antigen using an enzyme-linked immunosorbent assay (ELISA). Of nine species of predators examined to date *Collops vittatus* (58%), *Orius tristicolor* (38%), and *Geocoris* spp. (34%) were the most frequent predators of whitefly. *Lygus hesperus*, a major insect pest, was positive for whitefly in 23% of the samples. This high proportion of positive response for whitefly is significant because *L. hesperus* was the most abundant "predator" at our field sites.

In a separate experiment, we compared the efficacy of mass-reared *Orius insidiosus* against indigenous populations of *O. tristicolor*. The commercially-reared predators were released into field cages, then recaptured 48 hours later to examine by ELISA for the presence of whitefly egg antigen. Preliminary results showed that 21% of the released *O. insidiosus* and 13% of the indigenous *O. tristicolor* had whitefly egg antigen in their guts.

Currently, we are combining our ELISA results with predator and pest population data to estimate quantitative rates of predation and to obtain a better understanding of the effect that predaceous natural enemies have on sweetpotato whitefly populations. A new predator efficiency index (PEI) is being developed and will be validated using *Orius* spp. Data from our studies will be used to identify key predators of whitefly and test the utility of augmentative biological control.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biological Control

DATES COVERED BY REPORT: 1992-1993

SEARCHING AND PARASITISM BEHAVIOR OF SILVERLEAF WHITEFLY PARASITES

Parasitism of silverleaf whitefly ranged from 0 to ca. 90% on a variety of plant species in the Imperial Valley. Reasons for these differences were sought by studying the search behavior of the most common parasite of silverleaf whitefly, *Eretmocerus* sp. nr. californicus, on 5 plant species found in the Imperial Valley: velvet leaf (*Abutilon theophrasti*), cotton (*Gossypium hirsutum*), telegraph weed (*Heterotheca grandiflora*), melon (*Cucumis melo*) and sweet potato (*Ipomoea batatas*). The five plants represent broad taxonomic and morphological variation to help identify behaviors or behavioral pathways of the parasite that differ in frequency and duration.

The main behavioral pathway led from a female walking on a leaf surface, to encountering a host, assessing that host with antennation, probing beneath the host with the ovipositor and then to oviposition. Host assessment by antennation also led to probing the vasiform orifice for host feeding. Hosts were not used for both oviposition and host feeding. Duration of some behavioral activities, such as assessment of the host for oviposition, were strikingly different among the plant species. Differences also were found in the time budget of behavioral activities on the different plants. The total time for females of *E.* sp. nr. *californicus* spent in walking, antennation, probing and oviposition ranged from 25 to 60% among the five plants, while the remaining time was spent host feeding, grooming and resting. Host feeding was the most time consuming individual activity.

The willingness of adult parasites to remain on a leaf and search for whitefly nymphs was also different among the plant species. On sweet potato all of the females remained and searched for hosts, while on melon 63% of the females introduced to the leaf left without searching. The plant species had a profound effect on the ratio of initial probes leading to exertion of the ovipositor and repeating the probing process on the same host. On sweet potato repetitive probing of the same host was common while on melon it was rarely observed, that is most egg depositions resulted after the initial probe. We have discovered a mechanical factor in ease of egg deposition by the parasite related to the morphology of the host plant leaf and the position of the host nymph.

Percentage parasitism in laboratory trials also were markedly different among the host plant species, as expected from the field survey. However, the greatest percentage of ovipositions following assessment of a host nymph was on melon at 56%, while the remaining plants ranged from 23 to 30%. In this context percentage parasitism on melon should be high, but the survey data indicated that melon had little or no parasitism in the field. This low parasite activity relates to a female's unwillingness to remain on melon or other plants with hairy leaves and search for whitefly hosts and the relative ease of egg deposition under the host nymphs. We have also quantified a behavioral preference by *E.* sp. nr. *californicus* for oviposition under early instars of *B. argentifolii*.

These findings indicate important biological distinctions among the host plants in the mixed agricultural systems attacked by silverleaf whitefly, and indicate specific traits in the parasite which can be sought in additional species of natural enemies when they are introduced into the system.

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DATES COVERED BY REPORT: 1992 - 1993

BIOLOGICAL CONTROL OF *BEMISIA TABACI* INFESTING GREENHOUSE POINSETTIA

Releases of the parasitoid, *Encarsia luteola*, and the predatory coccinellid beetle, *Delphastus pusillus*, were evaluated for their ability to control *Bemisia tabaci* infesting greenhouse-grown poinsettias. To asses the impact of these releases, three treatments, each replicated three times, were used: (a) a complete exclusion of natural enemies cage, (b) an identical exclusion cage receiving natural enemy releases as a control for cage effects, and (c) releases of natural enemies onto plants within the greenhouse but outside of either cage. Weekly releases of *E. luteola* were initiated the week the plants entered the greenhouse and three releases of *D. pusillus*, one week apart, were made when *B. tabaci* populations rose dramatically 9 weeks into the trial. Release rates for both natural enemies were 1 insect per plant per week. Leaf samples were collected weekly and were later examined with the aid of a dissecting microscope. The numbers of live whiteflies were recorded by developmental stage as were the numbers of dead (resulting from natural causes, *D. pusillus* predation, or *E. luteola* host-feeding) and parasitized whitefly nymphs. No significant differences in whitefly densities between the two natural enemy release treatments were observed suggesting the absence of a cage effect on whitefly populations. Whitefly densities within the complete exclosure cages were significantly greater than the whitefly densities in either of the two natural enemy release treatments, indicating a significant impact of natural enemy releases on *B. tabaci* infestations. Whitefly damage to harvested plants within the natural enemy release areas was not significantly different from the damage level observed in the grower-treated area. The direct cost associated with *B. tabaci* biological control ($166.32 per greenhouse section) was approximately 5-times greater than the insecticide-based *B. tabaci* management program currently used by poinsettia growers. This cost differential can be reduced if the indirect environmental and worker-safety costs associated with insecticide use are included, and further reductions should accompany increased commercial availability of *D. pusillus*.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol.

DATES COVERED BY REPORT: 1993.

BEHAVIORAL COMPARISONS OF TWO STRAINS OF *ENCARSIA FORMOSA* AS POTENTIAL BIOLOGICAL CONTROL AGENTS OF *BEMISIA TABACI*

Comparative evaluations of two strains of *E. formosa* were conducted to determine whether the two strains varied in life history characteristics. The two strains, one originating from the Nile delta region of Egypt [I.D. # M92030] and one originating from a commercial insectary located in The Netherlands [I.D. # M93017], were shipped weekly as pupae on *Hibiscus rosa-sinensis* L. (hibiscus) from the USDA Biological Control Lab in Mission, TX to U.C. Davis. These two strains had been cultured in the Mission lab for 5-10 generations prior to their shipping to Davis. Upon arriving at Davis, the leaves containing the parasitized whitefly nymphs were placed in separate small sleeve cages to facilitated collection of emerging adults. The numbers of hosts attacked per unit time as a function of host densities, or functional response curves, were generated for the two *E. formosa* strains. A one day-old individual was placed in a 24 cm diameter by 25 cm high cylindrical sleeve cage for three days. The cage contained a three-leaf poinsettia plant (cv. 'Lilo' with a total adaxial surface area of approximately 475 cm^2) infested with 3-40 third instar *B. tabaci* nymphs. A minimum of 30 individuals (at 1 natural enemy per plant) was examined for each strain. A set of 30 three-leaf poinsettia plants infested with third instar *B. tabaci* nymphs were also placed in the sleeve cages for the same three-day period but without the addition of natural enemies. These plants were used as experimental controls to differentiate between intrinsic mortality and mortality resulting from parasitoid host feeding and parasitism. After the three day exposure to the infested poinsettia plant, the wasp was removed from the cage and the specimen was preserved in 70% EtOH. The plants were then held for ten days post-parasitoid exposure in a sleeve cage free of any natural enemies. After this period, the total number of *B. tabaci* nymphs, the number of nymphs killed by *E. formosa* host feeding, and the number of nymphs containing developing wasps were counted with the aid of a dissecting microscope. Thirty control plants infested with third instar whitefly nymphs were also treated and counted in the same manner. Leaves containing developing parasitoids were removed from plant's stem and were placed individually into petri dishes. The petri dishes were checked daily for adult emergence. Wasps that did not emerge within 28 days of removal of the three-leaf plant from the small, cylindrical sleeve cage were considered dead. Differences among natural enemy species in parasitoid host feeding, parasitism, and total whitefly mortality were detected using analysis-of-covariance (with host density as the covariant). Among parasitoid strain differences in percentage wasp emergence were detected using a one-way analysis-of-variance. The data were arcsin (x) transformed prior to analysis. No significant between-strain differences were detected in mortality from parasitoid host-feeding, parasitization, total mortality from parasitoid attack, or percent emergence of parasitoids emerging from parasitized *B. tabaci* nymphs on poinsettia. We are currently unable to detect any biological differences between the Commercial and Nile Delta strains of *E. formosa* for the four traits examined. Hence, we would therefore predict no overall difference in efficacy between the two strains when released into poinsettia greenhouses.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1992-1993.

THE INFLUENCE OF TOMATO CULTIVAR ON *BEMISIA TABACI* BIOLOGICAL CONTROL

The goal of the project was to assay processing tomato cultivars as to their compatibility with the use of natural enemies. Biological control of *B. tabaci* will probably be the greatest in cultivars where *B. tabaci* reproduction is the lowest and leaf trichome densities are the lowest. When *B. tabaci* reproduction is suppressed population growth will be minimized, and when leaf trichome densities are low the searching efficiency of natural enemies are maximized. Two commercial cultivars were selected based upon their suitability for *B. tabaci* population growth and influence on natural enemy searching efficiency. Previous studies indicated that the tomato cultivar 'Alta' was extremely susceptible to whitefly oviposition and its leaves were covered with extremely dense trichomes. These two parameters suggest that *B. tabaci* population growth on this cultivar should be rapid and that natural enemy search efficiency would be greatly reduced due to dense trichomes. In contrast, whiteflies oviposit 1/3 fewer eggs on the tomato cultivar 'VF145B7879' and the trichome densities on its leaves were approximately 1/4 less dense than 'Alta'. Therefore, *B. tabaci* population growth on this cultivar should be reduced by comparison to 'Alta' and natural enemy search efficiency should be increased due to the lower density of trichomes. To test these predictions the following study was conducted. Four enclosure cages measuring 1 m wide x 1.2 m high x 2 m long were positioned in a greenhouse maintained at an average temperature of 27C and a 16L:8D light cycle. Twelve 1-mo old tomato transplants were planted in 4-liter pots into each cages, two cages were planted with 'Alta' and two with 'VF145B7879'. Whitefly populations were established in all four cages by inoculating each cage with 100 adult *B. tabaci* per week for three weeks. After this inoculation, one cage of each cultivar received weekly releases of the predatory coccinellid beetle, *Delphastus pusillus* LeConte at the rate of 1 adult beetle per plant. Six randomly selected plants from each cage were sampled weekly for ten weeks. From each plant, 1 leaf was selected at random from the top third, the middle third, and the bottom third of the plant. The density of immature *B. tabaci* were counted on entire leaves with the aid of a dissecting microscope and the surface area of each leaf was determined with a Licor leaf area meter. The study was replicated four times and treatments were assigned to the cages so that each cage acted as a control or *D. pusillus* release treatment for each tomato cultivar exactly once among the four replicates. Significant among-treatment differences in whitefly density were detected with a repeated measures ANOVA. As predicted whitefly population densities increased to higher levels on 'Alta' than on 'VF145B7879'. Likewise, *D. pusillus* was better able to reduce *B. tabaci* population densities on 'VF145B7879' than on 'Alta'. Laboratory measurements of beetle walking speeds indicated that walking speeds over trichome-dense 'Alta' were 10% slower than walking speeds over 'VF145B7879'. These results suggest that tomato cultivars may influence whitefly population dynamics not only by their susceptibility to *B. tabaci*, but also by their ability to influence the searching efficiency of whitefly natural enemies.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1991-1993

WHITEFLY PARASITE SURVEYS

Pre-release surveys in seven southeastern states and TX began in 1991. AZ and CA were added to the list in 1993. Eleven or 12 species of aphelinids and one platygasterid were distinguished: *Eretmocerus* sp. 1 nr. *californicus* (western), *Er.* sp. 2 nr. *californicus* (eastern), *Er.* sp. 3, *Er.* sp. 4?, *Encarsia formosa, En. luteola, En. meritoria, En. nigricephala, En. pergandiella, En.* sp. nr. *strenua, En.* sp. 1, and *En.* sp. 2. *Amitus* sp. was collected in small numbers in CA.

Color patterns of pupal and adult aphelinids, both males and females, were depicted in colored drawings made from templates. Also, RAPD PCR techniques yielded DNA-banding patterns of all exotic species in culture at MBCL and of most species native to the U.S. Generally, different *Encarsia* species showed distinctly different banding patterns, although bands of certain populations of *En. luteola* matched those of all *En. formosa*. The taxonomic significance of banding patterns in *Eretmocerus* was less clear.

Additional analysis of '91-'92 survey data revealed *Er.* sp. nr. *californicus* to be the most common species of parasitoid in greenhouses along the Gulf Coast and in North Carolina. *En. pergandiella* was the next most common species during the warm seasons, but during the cool seasons *E. luteola* and *E. nigricephala* increased in relative abundance.

A relationship was found between sex ratio and population density in *Er.* spp. Generally, males were much more common than females at densities under 0.008 pupae/cm^2 of leaf surface, whereas females were much more common than males at densities exceeding 0.15 pupae/cm^2.

The MBCL-reared Nile Delta strain of *En. formosa* was released on tomato in greenhouses at the University of Arizona (O. Minkenburg) and on poinsetta at the University of New Hampshire (J. Weaver). In both places initial results were extremely encouraging; however, since neither morphological nor genetic characters now suffice to distinguish the Nile Delta strain from local *En. formosa* strains, the tests must be repeated. Data from similar studies at Cornell University (J. Sanderson) and the University of Connecticut (R. McAvoy) have not yet been analyzed. In tests conducted at the University of California at Davis (M. Parrella), a commercial strain of *En. formosa* that had been reared on sweetpotato whitefly at MBCL for at least six generations performed as well against the pest as did the Nile Delta strain.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biological Control

DATES COVERED BY REPORT: May - December 1993

EVALUATION OF INDIGENOUS AND EXOTIC NATURAL ENEMIES OF *BEMISIA* IN SOUTHWESTERN DESERT AGROECOSYSTEMS

Seasonal trends in whitefly natural enemy populations in southwestern U.S. desert agroecosystems are currently being monitored at several study sites in Imperial County, CA. Overlapping crops at each site are managed to maintain continuous whitefly populations as hosts/prey for indigenous and exotic enemies. The current crop cycle includes melons (spring/summer), cotton (spring/summer), okra (spring, summer, fall), and broccoli (fall/winter/spring/summer). Although analysis of 1993 data is not complete, several patterns are apparent.

The dominant parasitoid in melons, okra, and cotton was *Eretmocerus* sp. *nr. californicus*. This species accounted for 60 to 100% of parasitoids in collections of whitefly on these host plants. Parasitism early in the season on melons was very low and very patchy, but increased significantly at some sites and later on cotton and okra at all study sites. *Encarsia luteola* accounted for most of the remaining parasitism, but *Encarsia meritoria* was occasionally found as well. In contrast, parasitism in broccoli through mid-October was due almost entirely to the two *Encarsia* species.

Whitefly mortality due to predation was considerable at certain times, and was especially notable early in the season. *Geocoris sp.* was the most frequently encountered predator at this time. Other predators included *Chrysoperla sp.*, *Orius sp.*, nabids, and reduviids in mid-season. During late summer and fall, populations of the coniopterygid *Semidalis* sp. increased substantially.

Beginning in July 1993, field cage and open-field releases of two parasitoids collected from foreign locations (*Eretmocerus* sp. from Padappai, India and *Encarsia formosa* from the Nile delta, Egypt) and mass-reared at the Mission Biological Control Laboratory in Mission, TX, were made at several desert locations (Imperial and Palo Verde valleys, CA; Paloma, AZ), primarily in cotton and okra. Whitefly populations were already very high and indigenous parasitoids had established in large numbers when releases were first made. To date, neither of the released species has been recovered in surveys. Further releases and surveys will be continued on winter and spring crops. Releases of additional exotic species are planned as well.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biological Control

DATES COVERED BY REPORT: August - December 1993

CONIOPTERYGIDS (NEUROPTERA) NOTED AS PREDATORS OF *BEMISIA* IN THE IMPERIAL VALLEY, CA.

Populations of a dusty-wing, *Semidalis* sp. (Neuroptera: Coniopterygidae), have been increasing through the fall months on *Bemisia* populations on various host plants in Imperial County, CA. Larvae of this neuropteran predator have been observed in large numbers feeding on immature whitefly on a variety of ornamentals, garden vegetables, and in field plantings of okra. Adult coniopterygids are about 3 mm in length and are covered with white waxy particles. Eggs are laid on leaf surfaces among whiteflies; the white and orange larvae reach a length of about 1 mm before pupating, which occurs in flattened silken cocoons spun alongside leaf veins.

Although there have been occasional reports in literature of dusty-wings as whitefly predators, very little is known of the bionomics of most species. This species was previously known only from males collected at light traps. Coniopterygids are generally associated with prey on arboreal and not herbaceous hosts. Studies are underway to evaluate the impact of this predator on whitefly populations.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 92-93

BIOLOGY AND BEHAVIOR OF *ERETMOCERUS* SP. NR. *CALIFORNICUS* FROM TEXAS

Parasitoid fitness is often related to the suitability of the plant species on which the pest host develops. Knowledge of these tritrophic interactions is important in predicting parasitoid effectiveness as well as in developing mass production strategies. Development rate of the south Texas species of *Eretmocerus* sp. nr. *californicus* was measured on *Bemisia tabaci* reared on cotton, sweetpotato, broccoli and tomato at 27°C. The greatest percent female emergence from *B. tabaci* on all four host plants occurred on the 17th day after exposure (range = 15-25 d). Male development was nearly identical to that for females except males on tomato took over a day longer.

The interaction of food and host plant on longevity was studied using parasitoids reared on *B. tabaci* maintained on cabbage and cotton. Females reared from hosts on either plant showed no differences in longevity when fed either honeydew or nothing. Female parasitoids lived significantly longer on honey than when provided host larvae and their honeydew. There were some interactions between host plant and longevity for male survival.

Behavioral patterns were videotaped for two hours during each of the first two days after parasitoid emergence; several distinct behaviors were identified, timed and compared using an event recorder. Females spent most of their time in handling behaviors associated with oviposition and host feeding. Time allocated to host feeding was much greater than that reported for any other parasitoid of whiteflies. There were little apparent differences in the allocation of specific behaviors between the first and second day. Collateral fecundity data showed that females are capable of producing over 40 progeny in a single 24-hr period.

INVESTIGATOR'S NAME(S): Walker A. Jones[1], D. F. Wolfenbarger[1], and A. A. Kirk[2]

AFFILIATION & LOCATION: [1]USDA-ARS-Subtropical Agricultural Research Laboratory (SARL), Weslaco, TX, & [2]USDA-ARS-European Biological Control Laboratory, Montpellier, France

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 92-93

RESPONSE OF NATIVE AND EXOTIC PARASITOID ADULTS TO INSECTICIDE RESIDUES

The effectiveness of parasitoids of the sweetpotato whitefly *Bemisia tabaci* (Gennadius) in a multi-crop and multi-pest system will require the use of insecticide tolerant parasitoids or materials with low residual activity or high selectivity because other pests still require insecticide for their control. Tests were conducted to determine the susceptibility of four parasitoids of *B. tabaci* to seven cotton insecticides. The parasitoids were the native species *Eretmocerus* sp. nr. *californicus* Howard and *Encarsia pergandiella* Howard; the exotic species were *Eretmocerus mundus* Mercet and *Encarsia formosa* Gahan. Insecticides, applied as sprays to potted cotton plants at recommended rates, were amitraz (Ovasyn®), azinphosmethyl (Guthion®), bifenthrin (Capture®), buprofezin (Applaud®), cypermethrin (Ammo®), methyl parathion and thiodicarb (Larvin®), with a water control. Significant differences in toxicity were detected among the insecticides. Buprofezin was not toxic to any of the four parasitoids. When parasitoids were exposed to leaves sprayed two days previously, only amitraz, among the remaining insecticides, allowed significant levels of survival after two days. *E. mundus* demonstrated the greatest tolerance to insecticides, with 40% or more surviving 48 hr exposure to leaves sprayed with amitraz, thiodicarb and cypermethrin, although survival was much reduced after 96 hr exposure.

INVESTIGATOR'S NAME(S): T. A. Knauf & J. E. Wright

AFFILIATION & LOCATION: Fermone Corporation, Inc., Phoenix, AZ, and USDA-ARS, Weslaco, TX, respectively

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1992-1993

EVALUATION OF NATURALIS® L FOR CONTROL OF SWEETPOTATO WHITEFLY IN TOMATO FIELDS IN FLORIDA

The development of pesticide resistance by important insect species, the rising costs of pesticides, and increasing concern for the environmental impact of chemical pesticide use has sparked greater interest, investment, and research into alternative approaches to insect control. Such an alternative is represented by Naturalis-L, a biorational insecticide produced by Fermone Corporation of Phoenix, Arizona. Naturalis-L is a mycoinsecticide containing a conidial suspension of the naturally-occurring insect-specific strain (ATCC 74040) of the fungus *Beauveria bassiana*. During a six year test period, it has been evaluated in the laboratory, greenhouse, field, and under commercial production conditions on a variety of crops by Dr. James E. Wright at the USDA Subtropical Agricultural Research Laboratory at Weslaco, Texas. This work was performed under a Cooperative Research and Development Agreement with the USDA. In 1992 and 1993, numerous studies were initiated with other scientists at USDA/ARS locations and at state universities. The data indicates that Naturalis-L is effective in controlling boll weevil, thrip, cotton fleahopper, tarnished plant bug, and whitefly. Furthermore, the product had no adverse effect on beneficial insect populations.

In 1993, Dr. T.A. Knauf of Fermone Corporation initiated large-scale cooperator trials in Florida on commercial tomato acreages under an Experimental Use Permit. The results indicate that Naturalis-L, used alone, controls whitefly as well as traditional insecticide programs.

Naturalis-L is a significant breakthrough in technology since it is the first biorational product which, when applied alone, can control whitefly in tomatoes. Applied by itself, or in combination with other biorational or traditional insecticides, the product can make a significant contribution to Integrated Pest Management (IPM) programs.

INVESTIGATOR'S NAME(S): T. A. Knauf & J. E. Wright

AFFILIATION & LOCATION: Fermone Corporation, Inc., Phoenix, AZ, and USDA-ARS, Weslaco, TX, respectively

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1992-1993

FERMONE EXP 7744: A BIORATIONAL INSECTICIDE FOR WHITEFLY CONTROL
A Review of Research and Cooperator Trials in Florida and Texas Greenhouses

Naturalis bioinsecticides are formulated products containing a naturally-occurring strain (ATCC 74040) of the insect-specific fungus *Beauveria bassiana*. Naturalis-L has been evaluated in the laboratory, greenhouse, and in the field for six years. During this period, formulations and application timing, procedures, and technology were refined and improved significantly. Originally targeted toward boll weevil (*Anthonomus grandis*) control, the product also showed activity against cotton fleahopper (*Pseudatomoscelis seriatus*) and sweetpotato whitefly (SPW) (*Bemisia tabaci*) in subsequent studies. In 1991, Naturalis-L was field tested on cotton and vegetables in order to study its effect on SPW. In 1992 and 1993, under an Experimental Use Permit, studies were expanded to include researchers and commercial cooperators in six states. Due to the devastation caused by the whitefly in 1991 and 1992, this insect became an important focus in the Naturalis Project. Upon urging from nurserymen and the subsequent expansion of the E.U.P. to include ornamentals, commercial trials began in Texas and Florida greenhouses. During the last quarter of 1992 and the last half of 1993, the effect of Naturalis bioinsecticides (Fermone EXP 7744) on whitefly in greenhouse grown ornamentals was evaluated. The results of 1992-1993 research and cooperator trials indicate that in field crops and ornamentals, Naturalis bioinsecticides show significant efficacy in controlling SPW under a wide variety of commercial production conditions, whether applied alone or in combination with conventional chemical insecticides. Furthermore, beneficial insect populations are not adversely affected where Naturalis bioinsecticides are used.

INVESTIGATOR'S NAME(S): Lawrence A. Lacey and Alan A. Kirk

AFFILIATION & LOCATION: USDA-ARS, European Biological Control Lab., Montpellier, France

RESEARCH & IMPLEMENTATION AREA: Section D: BioControl

DATES COVERED BY REPORT: Aug. 1991 - present

FOREIGN EXPLORATION FOR NATURAL ENEMIES OF *BEMISIA TABACI*

Foreign exploration for natural enemies of *Bemisia tabaci* has been conducted by the USDA European Biological Control Laboratory over a broad geographic range under diverse climatic and environmental conditions since August 1991. A wide range of host plants were positive for *B. tabaci* over the geographic range of our collections. With the exception of crucifers, this host range reflects the same diversity of plants that are attacked in the U. S. However, silverleaf symptoms in squash, an indication of infestation with the B biotype, was observed only in Egypt and Cyprus. The plants most commonly infested throughout the collection area were *Lantana camara* and eggplant.

As of November, 1993 72 shipments of natural enemies have been made from the collecting areas to USDA quarantine facilities in the U. S. and the EBCL. Parasitic Hymenoptera, insect predators and fungal pathogens were collected in eight countries (France, Spain, Greece, Egypt, Cyprus Pakistan, India and Nepal). Nineteen species of natural enemies including *Encarsia* and *Eretmocerus* species, predator insects and several isolates of *Paecilomyces fumosoroseus* and other fungi have been provisionally identified from this material.

The most important isolates of fungi in terms of epizootic activity are strains of *P. fumosoroseus* from Pakistan. Selected isolates have been sent to cooperators in the United States for screening. Representative cultures have also been shipped to the USDA collection of entomopathogenic fungi in Ithaca, New York. Due to the feeding mechanism of whiteflies, only fungi appear to offer the only potential for microbial control of *B. tabaci*. Most of our exploration to date has been made in relatively dry locations, thereby lowering the possibility of finding fungi. In those areas where *P. fumosoroseus* has been found, its incidence has been correlated with the rainy season (Pakistan and Nepal) or high humidity (Madras). Many of our collections during 1994 will be made in the humid tropics (South America, Southeast Asia) in order to maximize the possibility of finding entomopathogenic fungi of *B. tabaci* and other insects.

Concomitant with exploration for natural enemies, specimens of *B. tabaci* were also collected in each of the eight countries and preserved for esterase profile and DNA analyses. Results of these analyses will be reported in an abstract in section A.

In addition to continuing the collection and shipment of natural enemies in 1994 and beyond, in-depth studies have been initiated with French colleagues at EBCL and INRA in Montpellier and St. Christol to elucidate the factors that govern the population dynamics of *B. tabaci* and its natural enemies. Understanding these parameters will enable optimal utilization of introduced biocontrol agents.

INVESTIGATOR'S NAME(S): L. Lacey & A. A. Kirk

AFFILIATION & LOCATION: USDA-ARS-European Biological Control Laboratory (EBCL), Montpellier, France

RESEARCH AND IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 92-93

FOREIGN EXPLORATION FOR NATURAL ENEMIES OF *BEMISIA TABACI* AND RELATED ACTIVITIES

Results of SPW characterization showed that the 'B' biotype was present in Spain, Cyprus, Egypt and Pakistan. Seventy-three shipments of SPW natural enemies from ten countries have been made to the U.S. Fourteen parasitoid species and four predator species have been identified. More than 100 isolates of fungal pathogens including *Poecilomyces fumosoroseus* from arid areas of Pakistan were sent to the U.S. Significant advances have been made in installing and equipping the pathology laboratory, greenhouse, quarantine and rearing facilities at the EBCL, Montpellier. This has enabled research in the following areas to be initiated: a study of environmental factors in relation to the efficacy of *Paecilomyces* and interaction between host plants/parasitoids/pathogens.

INVESTIGATOR'S NAME(S): Jesusa Crisostomo Legaspi[1], Raymond I. Carruthers[1], Donald A. Nordlund[1], Jose A. Correa[1], Allen C. Cohen[2], Dennis Holbrook[3] and cooperators

AFFILIATION & LOCATION: [1]USDA, ARS, Biological Control of Pests Research Unit, Weslaco, TX; [2]USDA-ARS, Phoenix, AZ; [3]South Tex Organics, Mission, TX

RESEARCH & IMPLEMENTATION AREA: Section D: Biological Control

DATES COVERED BY REPORT: October 1992 - October 1993

EFFECT OF INUNDATIVE RELEASES OF THE PREDATOR, *CHRYSOPERLA RUFILABRIS* (NEUROPTERA) TO CONTROL SWEETPOTATO WHITEFLY IN AN ORGANIC FIELD CROP

We studied the development of a native predator, the green lacewing, *Chrysoperla rufilabris* feeding on the sweetpotato whitefly (SPW), *Bemisia tabaci* reared on different plant hosts. The different plant hosts used were poinsettias, cucumbers, cantaloupes, and lima beans. Preliminary analysis of the data showed that *C. rufilabris* larvae weighed more, developed faster and completed a life cycle when fed SPW from cantaloupes and cucumbers compared to *C. rufilabris* that were fed on SPW reared from lima beans. Samples of *C. rufilabris* that were provided different diets and SPW reared from the different plants were sent to A. C. Cohen, USDA-ARS, Phoenix, AZ for follow-up studies on analyses of lipid and fatty acid classes.

During Spring 1993, we released *C. rufilabris* in caged watermelon plants (61 x 61 x 66 cm) in an organic grower's field in Mission, TX. The different treatments were the following: 10, 25, and 50 predator larvae per cage and the control where no *C. rufilabris* were released. Each treatment and control had 10 replicates. Analyses of the data showed that caged plants with *C. rufilabris* had significantly lower numbers of SPW compared to the control plants. On some occasions, plants where 50 lacewing larvae were released had significantly lower numbers of SPW compared to plants where 10 and 25 larvae/cage were released. On other sampling occasions, 10 predator larvae per cage were enough to control SPW. Significant differences were noted in the numbers of SPW eggs, first-instar larvae, and second-instar larvae. Fluctuations of densities of SPW adults were monitored by use of yellow sticky cards. Ten sticky cards (about 50 cm above the ground) were placed randomly along the border of the field. Weekly counts of SPW adults from yellow sticky cards ranged from 4.2 to 375 SPW adults per card. The peak of whitefly activity occurred the week before May 26 which corresponds to the harvesting dates of melons. Additional plant measurements included leaf area, dry weight of the leaves, and plant canopy width. Weather data were recorded by use of an Omnidata® logger. Temperature, humidity, rainfall, leaf wetness, and solar radiation were recorded throughout the field season. The meteorological information will be related to the population dynamics of sweetpotato whitefly. Based on our results, there is potential for use of *Chrysoperla rufilabris* in inundative release programs. The constraints for use of such a tactic will be the development of the technology to produce *Chrysoperla* efficiently and economically.

INVESTIGATOR'S NAME(S): H. J. McAuslane, F. A. Johnson & D. L. Colvin

AFFILIATION & LOCATION: University of Florida, IFAS, Gainesville, Florida

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: June - November, 1993

PARASITISM OF SWEETPOTATO WHITEFLY IN PEANUT AND SOYBEAN IN FLORIDA

Rates of parasitism of sweetpotato whitefly by aphelinid parasitoids were measured on 6 commercial peanut cultivars which have been field-tested for 2 years for resistance to sweetpotato whitefly. In another field experiment, rates of parasitism were compared among peanut and 3 soybean isolines varying for levels of pubescence.

Parasitism in commercial peanut cultivars - Parasitism of sweetpotato whitefly by aphelinid parasitoids was assessed in 6 cultivars (Sunrunner, Southern Runner, Florunner, Marc I, GK 7, AT 127). Details of planting and sampling are in McAuslane *et al.* Section E. Parasitism rates were estimated in 3 ways: 1) directly counting parasitized and unparasitized 4th instars on both surfaces of the peanut leaflet, 2) holding foliage in cardboard cans in the laboratory, and counting emerged parasitoid adults as a percentage of total emergence (whiteflies and parasitoids), and 3) counting exuviae from which parasitoids emerged as a percentage of total exuviae (those from which whiteflies emerged and from which parasitoids emerged).

Parasitism (estimated by method 1 above) increased in an almost linear fashion from 0% on July 20 to 92.5% (ranging from 86.5 to 97.6%) on October 8. Numbers of parasitized 4th instars peaked on September 28 at 1.85 per leaf (ranging from 0.97 to 2.65). Parasitism estimated by whitefly pupal cases (method 3 above) averaged 98.1% (ranging from 95.7 to 100%). We found no consistent differences among cultivars. Emergence data and species contribution to parasitism have not yet been analyzed.

Parasitism in soybean isolines - Rates of parasitism of sweetpotato whitefly were compared on Sunrunner peanut, and on 3 isolines of soybean (glabrous, pubescent and hirsute) obtained from E. Hartwig, Stoneville, MS. Peanuts were planted on June 6, and soybeans on June 30 in Alachua Co., FL. Plots were 8 rows wide and 6.1-m long, and each of the 4 plant types was replicated 4 times. Sampling began August 4 and continued at 10-day intervals until October 14. We picked a single leaflet from the 4th fully expanded leaf from the top of 20 peanut plants per replicate and a single leaflet from the 6th to 3rd leaf of 20 soybean plants per replicate. In the laboratory, discs measuring 3.34 cm^2 were cut from each leaflet with a cork borer, and the number of eggs, young instars (1st to 3rd), parasitized 4th instars, parasitized 4th instars, red eye nymphs and exuviae were counted on top and bottom surfaces.

Rates of parasitism increased from 0% on August 4 to 67% in peanut (10 parasitized and 5 unparasitized 4th instars), 92% in pubescent soybean (133 parasitized and 11 unparasitized), 60% in hirsute soybean (241 parasitized and 159 unparasitized) and 82% in glabrous soybean (9 parasitized and 2 unparasitized) on October 14. Rates of parasitism are only meaningful for hirsute and pubescent soybean due to the small number of 4th instars on peanut and glabrous soybean. Parasitism appears to be reduced on the most pubescent soybean isoline.

INVESTIGATOR'S NAME(S): O.P.J.M. Minkenberg, R. Berens[1], and J. C. Palumbo[1].

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1992 to December 1993.

FIELD EVALUATION OF INSECT FUNGI TO CONTROL SWEETPOTATO WHITEFLY ON LETTUCE AND COLE CROPS

Work begun in December 1992 to investigate the potential of entomophagous fungi to control whiteflies on short-term crops, such as lettuce and other winter vegetables. We decided to initiate greenhouse and field trials with commercially available fungal products, viz. Mycotal, *Verticillium lecanii* (produced by Koppert B.V., the Netherlands), Natural L225, *Beauveria bassiana* (produced by Fermone Co., Phoenix), and PFR, *Paecilomyces farinosus* (produced by W.R. Grace). The objectives were to determine the efficacy of these insect fungi on vegetables in the desert, and to develop effective e.g., oil-based, solutions of fungus spores, quality control, and application techniques e.g., sprinkler irrigation, to improve biological control results.

The first greenhouse trial indicated after 7 and 11 days that PFR was the better agent with higher mortality of whitefly eggs and small nymphs than the two other agents. With regard to the red-eyed nymphs, only PFR caused mortality (ca. 30%) with zero mortality for Mycotal, Naturalis, and the 'control' solutions.

The sweetpotato whitefly, *B. tabaci*, is a major economic pest on vegetables and overwinters on crops such as lettuce and broccoli in the low desert of Arizona. An IPM approach will be necessary to reduce the use of pesticides, which will require the use of soft chemicals or solutions that are compatible with parasitoids and predators. Insect fungi have been shown to be pathogenic to whiteflies and need to be explored for potential use in these short term crops. Oil-based solutions and use of sprinklers might provide means to achieve germination of spores and effective biological control under the relative dry conditions of the desert.

Next year large scale applications will be conducted in experimental fields of lettuce and broccoli to determine if significant levels of whitefly suppression can be achieved. In addition, laboratory test will be conducted to examine the effects of these fungi on parasitoids and predators and to determine the compatibility of these fungi with other natural enemies.

INVESTIGATOR'S NAME(S): O.P.J.M. Minkenberg, R. Malloy, J. Kaltenbach, C. Leonard, K. Grish, R. Greatrex[1], and K. T. Alcock[1].

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1992 to December 1993

MASS-REARING OF *ERETMOCERUS* NR. *CALIFORNICUS* FOR AUGMENTATIVE BIOLOGICAL CONTROL OF SWEETPOTATO WHITEFLY IN FIELD CROPS AND GREENHOUSE TOMATOES

The sweetpotato whitefly continues to be a devastating pest in U.S. agriculture. The presence of a mass-rearing at a University of Arizona site allows us to conduct large-scale field and greenhouse studies for various crops, which are necessary to determine effectiveness of a biological control method employing the parasitoid *Eretmocerus* nr. *californicus*.

A mass-rearing of this native, aphelinid parasitoid was started to enable augmentative biological control releases against the sweetpotato whitefly, *Bemisia tabaci*, in large field plots. This parasitoid was chosen because it is the dominant parasitoid of whiteflies in the Southwest, it can sustain the extreme heat and drought of the desert, and it does not hyperparasitize. *Er.* nr. *californicus* reproduces successfully on various species of whiteflies, has a sex ratio of approximately 1:1, and exhibits some host-feeding. The mass-rearing was set up in six greenhouses and two buildings at Tucson. A number of problems, such as contamination by the parasitoid *Encarsia formosa* and sooty molds, were solved. The current production is about a million parasitoids per week.

Numerous tests are conducted to improve parasitoid production and quality e.g., examining the effect of additional feeding, estimating the functional response, measuring female longevity, and estimating the effects of transportation. Large scale releases of the parasitoid *Er.* nr. *californicus* will be conducted in commercial fields of cotton and melons and in greenhouse poinsettia and tomatoes to determine its effectiveness in whitefly control.

INVESTIGATOR'S NAME(S): Charlie Moomaw, James Woolley, Mike Rose and David Riley

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RESEARCH & IMPLEMENTATION AREA: Section D: Biological Control

DATES COVERED BY REPORT: 1993

EVALUATION OF NATURALLY OCCURRING PARASITIC HYMENOPTERA ATTACKING *BEMISIA TABACI* (GENN.) IN TEXAS

Outbreaks of the whitefly, *Bemisia tabaci,* in Texas reached the crisis stage during 1991. The outbreaks occurred in the lower Rio Grande Valley where insecticide use is widespread and common. A rich complex of at least 5 species of parasites in the genera *Eretmocerus* and *Encarsia* that attack the whitefly have been collected in Texas.

Non-chemically treated refuge plantings of sunflower, kale and collards were created in association with cotton to provide enhanced habitats for the conservation of parasitic hymenoptera throughout the year. Evaluation of these natural enemies has emphasized the measurement of relative whitefly population densities and statistical dispersion, status of individual whitefly populations and changes in parasite complex through time, as well as exclusion cage comparisons. The sampling method targets well developed 4th instar whitefly.

Data indicates a potential for the parasites to regulate whitefly populations in these habitats. Measurements of direct parasitism on 4th instar whitefly range from 20% to as high as 82% in late summer, just prior to defoliation and harvest of cotton, with corresponding total whitefly mortalities at greater than 90%. Parasite populations exhibit an ability to rapidly catch up to whitefly populations subsequent to regional cotton defoliation and mass emigration of whitefly into refugia. Phenology of the parasite complex generally proceeds with the *Eretmocerus* sp. most abundant early season and a complex of *Encarsia* sp. taking over later.

INVESTIGATOR'S NAME(S): Ru Nguyen and Fred D. Bennett

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RESEARCH & IMPLEMENTATION AREA: Section D: Biological Control

DATES COVERED BY REPORT: 1990-1993

IMPORTATION, RELEASE AND FIELD RECOVERY OF PARASITES OF *BEMISIA TABACI* IN FLORIDA (1990-1993)

For over a century the sweetpotato whitefly was considered a minor pest in Florida. In 1987 a severe outbreak on tomatoes in southwest Florida signaled multi-million dollar annual damage losses. To complement the native biotic factors in IPM programs, the introduction of exotic parasitoids began in Florida in late 1990. The following parasites were imported from November 1990 through March 1993:

Amitus sp. (November 9, 1990 from Puerto Rico)
Encarsia sp. (December 18, 1990 from India)
Encarsia sp. (March 19, 1991 from Guatemala)
Encarsia sp. (July 12, 1991 from Sudan)
Encarsia lutea (November 20, 1991 from Israel)
Encarsia sp. (July 18, 1992 from Hong Kong)
Encarsia sp. (July 29, 1992 from China)
Encarsia sp. (February 3, 1992 from Thailand)
Encarsia sp. (January 27, 1993 from Brazil)
Eretmocerus sp. (March 19, 1991 from Guatemala)
Eretmocerus sp. (July 12, 1991 from Sudan)
Eretmocerus mundus (November 20, 1991 from Israel)
Eretmocerus sp. (July 18, 1992 from Hong Kong)
Eretmocerus sp. (July 29, 1992 from China)
Eretmocerus sp. (March 20, 1993 from Thailand)

After rearing on hibiscus in plastic cylinders in the quarantine greenhouse in Gainesville, any species that looked promising was cultured in large numbers. Permits for field releases were requested from state and federal authorities.

Over 300,000 *Amitus* sp. from Puerto Rico were released in 1991-92 in Alachua, Bradford, Collier, Dade, Hillsborough, Levy, Polk, Manatee, Okeechobee, Orange, Palm Beach and Volusia counties and were recovered in Alachua, Hillsborough, Orange and Volusia counties.

About 150,000 *Encarsia* spp. (from India and Guatemala) and *Eretmocerus* spp. (from Guatemala and Sudan) were released in Hillsborough, Dade, Orange, Alachua and Volusia counties during 1992; and 250,000 *Eretmocerus* sp. (from Hong Kong) were released in Marion, St. Lucie, Collier, Polk, Hillsborough, Volusia, Palm Beach and Dade in 1993. All these parasites were recovered from the field about 3-4 weeks after release. In the field they increased in number dramatically, especially *Eretmocerus* spp. (from Hong Kong and Sudan) and suppressed *Bemisia tabaci* populations in several locations in Dade, Marion, Volusia, Orange and Palm Beach counties. Other species will be released after they are cleared through quarantine.

INVESTIGATOR'S NAME(S): David G. Riley

AFFILIATION & LOCATION: Texas Agricultural Experiment Station, Weslaco, Texas

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: January 1993 - December 1993

THRESHOLDS OF WHITEFLIES IN MELONS

The effect of the b-strain sweetpotato whitefly (SPWF) on melons was quantified in 1992 and 1993. An increase in total numbers of immature SPWF was associated with a decline in harvested melon weight, a decline in number of boxes, and increase in the size category number or number of fruit per box (which means a decrease in fruit size), a decrease in sugars, and increases in sooty mold and downy mildew. The relationship of different stages of SPWF with yield parameters suggest that SPWF large nymphs provide a better indicator of SPWF effects on yield than adults. The threshold treatments tested included three thresholds for nymphs and three for adults: (1) 0.5 large nymphs/7.6 cm^2, (2) 1 large nymph/7.6 cm^2, (3) 2 nymphs/7.6 cm^2 of leaf area, (4) 1 adult per leaf, (5) 3 adults per leaf, (6) 6 adults per leaf, (7) weekly sprays, and (8) an untreated check. The best threshold treatment tested was 0.5 large nymphs per 7.6 cm^2 of leaf area. Using this threshold imidacloprid applications resulted in a 40% increase in net return and resulted in a total of 0.25 lb AI/acre of material used.

INVESTIGATOR'S NAME(S): W. J. Roltsch[1] and C. H. Pickett[2]

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: March through October 1993

SILVERLEAF WHITEFLY NATURAL ENEMY REFUGES IN IMPERIAL COUNTY

Natural enemy refugia are presently being evaluated in the Imperial Valley for their potential in building and maintaining populations of silverleaf whitefly (SLWF) natural enemies, including parasitoids and generalist predators. Plots consist of two rows of refuge plants (interplanted sunflower, kale, and collards) alternating with 20 rows of crop (melon, cotton or broccoli). Two refuge plots (2 acres each) and corresponding check sites are being evaluated at a field station, whereas one refuge plot (5 acres) and check site are present at a second farm site (organic) in Imperial County. Currently, refugia are intended to be continually present throughout the year.

Eretmocerus nr. californicus, and *Encarsia luteola* populations were very low in newly created refugia and associated cotton crop during spring. Encarsia parasitism was generally low throughout the year, rarely exceeding 10% on any whitefly host plant included in the evaluations. *Eretmocerus* parasitism on sunflower has been as high as 80%, however it appeared to be commonly disrupted by the presence of lace bugs [Tingidae: *Corythuca morrilli*], which cause increased damage to leaves of sequential plantings of sunflower as the season progresses. Sunflower lasts for 2-3 months and must be replanted. It was determined that the native *Eretmocerus* seldom parasitized whitefly on kale and collards from May to September, with parasitism seldom exceeding 4%. During October, parasitism did increase to 20% on collards and remained at 2% on kale. Kale and collards can be planted in early spring with sunflower. As well established and well watered plants they will maintain relatively vigorous growth throughout the summer. Cole crops may only have a role as a parasitoid refuge plant following new parasitoid introductions. Sunflower may have an important role when grown in the spring and perhaps again in the fall. Several predators including, *Geocoris* spp. and *Hippodamia convergens* are very common on sunflower.

An additional plant is currently being considered as a refuge plant. Kenaf [*Hybiscus cannabinus*] has been determined to sustain high levels of *Eretmocerus* parasitism (75%) of SLWF. With this long season plant, it is conceivable that refuge strips could be planted in early spring and provide effective natural enemy habitats through October, thereby minimizing replanting costs and inconvenience.

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RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: August to November 1993

AREAWIDE ESTABLISHMENT OF *DELPHASTUS PUSILLUS*, A PREDATOR OF SILVERLEAF WHITEFLY, IN THE IMPERIAL VALLEY

An area-wide release of *Delphastus pusillus* was conducted in Imperial County and Mexicali, Mexico during August and September of 1993. Beetles were mass reared at CDFA greenhouses in Sacramento and mailed on a weekly basis for release into urban and rural home-sites selected for their presence of whitefly host plants and year around existence of ornamental vegetation, especially hibiscus. One thousand adult beetles (1: 1 sex ratio) were released at 13 rural home-sites, 10 urban home-sites in the communities of Brawley and El Centro, and 4 home-sites in Mexicali, Mexico . A second release of one thousand beetles was made several weeks later at six of the sites. Sleeve cages containing 100 beetles for seven days were used to evaluate initial release survivorship. Subsequently, each site has been sampled for late stage larvae , adults, and exuviae of older larvae and pupae on a 4 to 5 week basis. To date, reproduction has been confirmed at the majority of sites.

INVESTIGATOR'S NAME(S): M. E. Schauff[1], J. B. Woolley[2], M. Rose[2], G. Zolnerowich[2], G. Evans[3], and R. Williams[2].

AFFILIATION & LOCATION: Syst. Ent. Lab., USDA, NHB 168, Washington, D.C. 20560[1]; Dept. of Entomology, Texas A & M University, College Station, TX 77843[2]; Dept. of Entomology and Nematology, Univ. of Fla., Gainesville, FL[3]

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: Jan. 1993 - December 1993.

TAXONOMY OF *BEMISIA TABACI* PARASITES

Work on the taxonomy of parasites of *Bemisia tabaci* is now being conducted at several locations. A manuscript treating the six described species of *Eretmocerus* from North America is in progress (Rose and Zolnerowich). Illustrations are now complete and redescriptions are in progress. Results of mating studies suggest that additional undescribed species are present in North America. A protocol is in place directing native and imported *Eretmocerus* reared from *Bemisia* to TAMU. Work has begun on an illustrated key to *Eretmocerus* species attacking *Bemisia* worldwide.

A review of the species related to *Encarsia pergandiella*, the "*parvella*" or "*americana*" species groups is being undertaken (Woolley and Williams). At present, the group appears to include approximately a dozen described species and several undescribed species. Following taxonomic review of world species, they will concentrate on New World species attacking *Bemisia*. There are indications that *E. pergandiella* may consist of a widespread complex of host races, geographic races or cryptic species. Traditional taxonomic methods, experimental mating studies and morphometric characterization of size and shape differences will be used.

Work is in progress on development of a pictorial key to the N.A. species of *Encarsia* parasitic on whiteflies (Schauff and Evans). Each species will be diagnosed and keyed using illustrations of wings, antennae, habitus showing color patterns, etc. As an adjunct to the key, a limited number of sets of identified specimens on slides are being prepared. These slides sets will be available on long-term loan to laboratories conducting quarantine, rearing, or field releases of *B. tabaci* parasites.

Databases are being compiled for the world species of both *Encarsia* and *Eretmocerus*. These databases include information on names, types, distribution, literature, and biology.

A joint protocol has been established for all taxonomic work and a database has been established to track identifications of material related to *Bemisia* parasites.

All participants involved in the projects listed are interested in obtaining material of species relevant to SPWF control. We are especially interested in specimens which do not seem to fit established species limits or which might represent undescribed taxa.

INVESTIGATOR'S NAME(S): D. J. Schuster, L. S. Osborne J. F. Price, D. E. Dean, P. A. Stansly

AFFILIATION & LOCATION: University of Florida, Gulf Coast Research & Education Center, Bradenton, Florida

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: September 1992 - December 1993

INTEGRATION OF NATURAL ENEMIES FOR MANAGEMENT OF THE SWEETPOTATO WHITEFLY

The insect pathogenic fungus, *Paecilomyces fumosoroseus*, was applied once to pairs of tomato plants at an organic farm. Plants were sampled weekly from treated and untreated plants and examined for nymphs of the sweetpotato whitefly. The percent of nymphs infected with the fungus on sprayed plants ranged from 6.2 to 32.2% compared to 0.0 to 1.5% on unsprayed plants. The results indicate that the fungus can be established following a single application and that a single application is compatible with sweetpotato whitefly parasites.

A combination of whey, yeast and sucrose was applied to every other row of 50 foot by 12 row plots of tomato at the above organic farm site. Applications were made weekly and the number of lacewing eggs were counted weekly on plants in treated and untreated plots. The number of groups of eggs, the total number of eggs and the number of eggs per egg group were increased by the whey/yeast/sucrose applications.

The numbers of adult SPWF and insect predators were determined weekly on three unsprayed tomato plants by dropping a large, cylindrical trap on each plant, spraying each plant with pyrethrum, and aspirating the killed insects with a hand-held vacuum. The results suggest that there are a large number of predacious insects occurring on tomato plants that are not sprayed with conventional insecticides. By the end of the 14 week sampling period, the number of predators had increased to about 100 per plant. Spiders were the first predators to be detected on plants but *Orius* spp. were the most abundant.

INVESTIGATOR'S NAME(S): Alvin M. Simmons and Kent D. Elsey.

AFFILIATION & LOCATION: USDA-ARS, U. S. Vegetable Lab., Charleston, SC, 29414.

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: July - October 1993.

SEASONAL PARASITISM IN SOUTH CAROLINA

Seasonal parasitism levels of *Bemisia tabaci* were examined at five coastal South Carolina sweetpotato field locations. South Carolina, a location where *B. tabaci* occurs year round, provided an opportunity for examining parasitism under relatively low whitefly densities. Moreover, sweetpotato provided a vegetable crop with a long growing season. The five locations were, Beaufort, Edisto Island, John's Island, Charleston, and McClellanville, SC. In addition to collecting data on seasonal trends, we wanted to determine which parasitoids of *B. tabaci* are present here. Sticky traps were placed in sweetpotato fields (transplanted in June) and replaced weekly starting in early July. Additional samples of vacuum and plant material were made from various vegetable crops. Except for a pre-plant herbicide, and an early season herbicide treatment for one of the fields, no other pesticide was used on the sweetpotato. The number of parasitoids and adult *B. tabaci* were determined on each sticky trap, and the index of parasitism was based on the proportion of parasitoids relative to total number of *B. tabaci* and parasitoids captured. We found three species of *Encarsia* (*E. pergandiella*, *E. nigricephala*, *E. strenua*, as well as apparently *E. quantancei*), and *Eretmocerus californicus*. During the previous season, 1992, we identified three species. Overall parasitism across location and time was ca. 35%. Parasitism varied by location from ca. 10% in Charleston to ca. 50% in McClellanville. *E. pergandiella* and *E. nigricephala*, respectively, were the most abundant (84%) among the parasitoids. Parasitism varied over time, and was lowest in August.

INVESTIGATOR'S NAME(S): G. S. Simmons and O.P.J.M. Minkenberg.

AFFILIATION & LOCATION: Department of Entomology, University of Arizona, Tucson, AZ 85721.

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1992 to December 1993.

DEVELOPMENT OF AUGMENTATIVE BIOLOGICAL CONTROL FOR SWEETPOTATO WHITEFLIES ON COTTON AND FIELD VEGETABLES IN THE IMPERIAL VALLEY

In 1992 we started to investigate the potential of the native, aphelinid parasitoid *Eretmocerus* nr. *californicus* as a control agent in an augmentative biological control program against the sweetpotato whitefly, *Bemisia tabaci*, and we continued in 1993. The work was conducted in cotton fields in the Imperial Valley of California. Field cage studies with varying release rates of the parasitoid achieved parasitism levels as high as 80% along with whitefly control. The field cage studies of both 1992 and 1993 suggest that augmentative biological control with *E.* nr. *californicus* is an effective means of whitefly control, although the required release rate (> 10 parasitoids/plant) is high and not economically feasible (yet).

Open field releases of *E.* nr. *californicus* were also conducted in 1993. The results from these studies were less promising than the cage studies as overall parasitism was low and there was no significant reduction in whitefly levels in release fields relative to control plots at the end of the season. The highest level of parasitism achieved was on average 36%, which was significantly higher than control plots with 30% parasitism on August 12. High levels of whitefly immigration from spring melon fields probably reduced the effect of these releases.

B. tabaci continues to be a major economic pest in desert agriculture throughout the Southwest. An IPM approach will be necessary to combat this pest and information about potential strategies such as augmentation or conservation of natural enemies will be required to implement a true IPM program. Our cage studies suggest that *E.* nr. *californicus* can be an effective parasitoid against *B. tabaci* on cotton though it remains to be seen if these parasitoids can be effective outside of cages. If the major effect of cages is to limit the number of whitefly that migrate into the cotton, then our results suggest that augmentative biological control with *E.* nr. *californicus* may be useful as a control strategy in fields distant from source populations of whitefly immigrants or in years when valley-wide whitefly levels are low.

Next year large scale releases of parasitoids will be conducted in commercial field blocks of cotton to determine if significant levels of whitefly suppression can be achieved without use of cages. If funding permits, work on augmentative biological control will also be conducted in spring and fall melon.

INVESTIGATOR'S NAME(S): K. Ziegweid, O.P.J.M. Minkenberg, and R. D. Hennessey[1].

AFFILIATION & LOCATION: Department of Entomology, University of Arizona, Tucson, AZ, and [1]USDA-APHIS, Biological Control Laboratory, Mission, TX.

RESEARCH & IMPLEMENTATION AREA: Section D: Biocontrol

DATES COVERED BY REPORT: 1992 to December 1993.

PRE-INTRODUCTION SELECTION OF PARASITOIDS FOR AUGMENTATIVE BIOLOGICAL CONTROL OF THE SWEETPOTATO WHITEFLY ON GREENHOUSE TOMATOES

We are evaluating both native and exotic parasitoids in the genera *Eretmocerus* and *Encarsia* (Hymenoptera: Aphelinidae) for control of the sweetpotato whitefly, *Bemisia tabaci* on greenhouse tomatoes. The parasitoids examined so far include *Eretmocerus* nr. *californicus,* native to Arizona, *Er. mundus* from Spain, and *Er.* "A" and *Er.* "T" from the Padappai and Thirumala regions of India, respectively.

A uniparental parasitoid identified by RAPD-PCR as *Encarsia formosa* invaded all four experimental glasshouses during the second replicate. Whitefly levels decreased in all greenhouses and parasitism levels, mostly from this *Encarsia*, of 90% or higher have been achieved, with one greenhouse approaching 100% parasitism within an eight week period. These promising results need further replication in time.

We are currently using RAPD-PCR to determine if there are genetic differences between this invasive *Encarsia formosa*, a commercial strain, and a wild strain collected in Egypt. We will continue to evaluate the three *Encarsia* biotypes in the laboratory to determine if there are behavioral and/or physiological differences among these parasitoids using *B. tabaci* as the host.

TABLE D. Summary of Research Progress for Section D - Biological Control, in Relation to Years 1 and 2 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
D.1 Determine effects of indigenous natural enemies on regulating SPW populations.	Yr. 2: Continue survey; culture and study reproductive biology of beneficial species.	X		Surveys were continued in several states by both USDA and SAES personnel. Surveys of parasites reveled at least one *Eretmocerus* sp. together with *Encarsia* spp. in each region. In the southeastern U.S., up to 6 *Encarsia* spp. are known, in Texas 5 *Encarsia* spp., and in the southwestern desert regions 2 species. Parasitism rates vary seasonally and on different host plants. Some plants, both crop and weed hosts, are associated with low parasitism. Other crop and weed hosts show greater parasitism, exceeding 70% in some cases. The reasons underlying these host- plant differences are being investigated in the laboratory, and initially appear related to host-plant morphological differences. Several general predators have been noted as feeding on or associated with whitefly population. The role of any particular natural enemy or guild of natural enemies in regulating whitefly populations has not been determined, but comparison of regional faunal diversity indicates that natural enemies are responsible for some degree of population suppression.
D.2 Develop methods for enhancing habitats with refuge plantings to conserve natural enemies.	Yr. 2: Continue sampling; test inoculative parasitoid releases; determine SPW/parasitoid interactions.	X		Refuge plantings consisting of sunflower, kale, collard and kenaf established in Texas in association with unsprayed cotton plots. Quantitative, stage-specific data taken year round as rates of parasitization in refuge plantings indicates 3-4 species are seasonally common in Texas. Paired-cage experiments indicate that native parasites can have substantial impact in unsprayed refugia. Several studies have indicated candidate plant species for further evaluation as refugia plant. A native species, *Heterotheca grandifolia*, native to the desert southwest, and kenaf, a crop grown as a potential substitute for paper production harbor large numbers of whitefly parasitoids, (*Eretmocerus* sp.) The utility of these plants will be investigated over the next year. In certain agricultural systems, the seasonal cycle and cropping structure is highly conducive to whitefly outbreaks. This agro-ecological environment must be altered to encourage natural control of whiteflies. Creation of refugia for whitefly natural enemies is one element of this change. By enhancing and distributing areas with high parasites and predator densities, natural control may be facilitated.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
D.3 Identify new natural enemies in areas of SPW origin; foreign exploration, importation and release.	Yr. 2: Continue collections; assess biology and host plant relations; develop rearing techniques.	X		Foreign exploration for natural enemies of *Bemisia* spp. has been conducted by many different agencies over a broad geographic range under diverse climatic and environmental conditions. Parasitic Hymenoptera, insect predators and fungal pathogens have been collected and sent to quarantine facilities around the world. At least 19 species of natural enemies including *Encarsia* and *Eretmocerus* species, predator insects and several isolates of fungi are currently in culture in California, Florida, Texas, and France.
D.4 Determine natural enemy host selection processes and mechanisms.	Yr. 2: Study efficiency of host foraging mechanisms.	X		Studies have documented that host plant plays a significant role in the searching efficiency and control of *Bemisia* by various parasitoids. These findings suggest areas for further investigation. Recent studies have greatly increased our understanding of host-plant, host-whitefly, and natural enemy interactions; host plant effects (such as plant hairiness, glandular exudates, and plant nutritional quality) have been demonstrated to significantly influence the efficiency of natural enemies. Studies of interspecific interactions between natural enemies, including the impact of autoparasitic species, are now underway. One important topic needing further attention is a better understanding of natural enemy dispersal between different crops and reservoir host plants.
D.5 Inoculate/augment parasite and predator populations through propagation and release.	Yr. 2: Develop laboratory rearing procedures for select species.	X		Significant efforts were devoted to this goal during the past year. The results were variable depending on the natural enemy being evaluated, the crop and environment into which it was released. The results were encouraging.
D.6 Determine effects of pathogens on regulating SPW populations.	Yr. 2: Screen candidates for efficacy and effects on non-target organisms.	X		A large number of *Beauveria bassiana* and *Paecilomyces fumosoroseus* isolates from diverse geographic regions of North America and Asia were found highly effective against immature whiteflies in laboratory assays. Assays of selected isolates against the principal parasites and predators of whiteflies were initiated. Applications of oil-formulated *B. bassiana* and *P. fumosoroseus* produced highly variable levels of control in field and greenhouse trials. These initial results are promising, but indicate a need for much additional field testing of fungus formulations, including spray adjuvant controls.

Research Approaches	Goals statement	Progress Achieved Yes	No	Significance
D.7 Evaluate compatibility of pesticides with SPW natural enemies.	Yr. 2: Survey for geographic variation to pesticide exposure and select natural enemies with pesticide tolerance; identify pesticides that are compatible with natural enemies.	X		Cotton leaf residues of seven insecticides were tested for effects on four species of adult parasitoids. Buprofezin was non-toxic to all parasitoids; amitraz showed intermediate effects. *Eretmocerus mundus* from Spain exhibited some tolerance to the four insecticides.
D.8 Systematics of predators, parasites and pathogens.	Yr. 2: Continue survey; identify and voucher exotic material; implement protocols.	X		Extensive survey material curated and identified. A protocol was established and agreed to by ARS, APHIS, and SAES scientists for vouchering of specimens from importations, centralized database for all importations established), databases established for *Encarsia* and *Eretmocerus* of world, several potential new species identified in U.S., crossing studies conducted on *Eretmocerus* and *strenua* and *parvella* groups of *Encarsia*.

RESEARCH SUMMARY

Section D: Biocontrol

Compiled by:

Committee

There are numerous natural enemies of *Bemisia tabaci* recorded from many parts of the world. These, as well as new candidate species, form a potential framework for developing the tools to manage sweetpotato whitefly populations using one or more of the many biological control approaches. Biological information about each species is needed, as well as rearing protocols and habitat adaptability knowledge. A concise and well coordinated effort is being made to develop this information for *B. tabaci's* natural enemies.

D.1 Determine effects of indigenous natural enemies on regulating SPW populations.

Surveys in cultivated crop, weed and urban planting systems have revealed a number of parasite species attacking *B. tabaci*. In the southeastern U.S., up to 6 *Encarsia* spp. are known, in Texas 5 *Encarsia* spp., and in the southwestern desert regions 2 species. Parasitism rates vary seasonally and on different host plants. The reasons for host- plant differences need to be investigated, but initially appear related to host-plant morphological differences. Several general predators have been noted as feeding on or associated with whitefly populations. Quantification of the impact of any particular natural enemy or group of natural enemies in regulating whitefly populations has not been determined, but comparison of regional faunal diversity indicates that natural enemies are responsible for some degree of population suppression.

D.2 Develop methods for enhancing habitats with refuge plantings to conserve natural enemies.

Parasite refugia plantings such as sunflower, kale, collard and kenaf are being studied in Texas in association with unsprayed cotton plots. Rates of parasitization in refuge plantings indicates 3-4 parasite species are seasonally active and can have substantial impact in unsprayed refugia. Candidate plant species for further evaluation as refugia plants are *Heterotheca grandifolia*, native to the desert southwest, and kenaf, a crop grown as a potential substitute for paper production. These species harbor large numbers of whitefly parasitoids, (*Eretmocerus* sp.). Certain agricultural systems are highly conducive to whitefly outbreaks. Refugia for whitefly natural enemies by enhancing parasite and predator densities in areas may be a system change that facilitates biological control.

D.3 Identify new natural enemies in areas of SPW origin; foreign exploration, importation and release.

Parasitic Hymenoptera, insect predators and fungal pathogens have been collected and sent to quarantine facilities around the world. At least 19 species of natural enemies including *Encarsia* and *Eretmocerus* species, predator insects and several isolates of fungi are currently in culture in California, Florida, Texas, and France.

D.4 Determine natural enemy host selection processes and mechanisms.

Research results show that the host plant plays a significant role in the searching efficiency and control of *Bemisia* by various parasitoids. Plant hairiness, glandular exudates, and plant nutritional quality are a few plant characteristics that have been demonstrated to significantly influence the efficiency of natural enemies. Studies of interspecific interactions between natural enemies, including the impact of autoparasitic species,

are now underway. One important topic needing further attention is a better understanding of natural enemy dispersal between different crops and reservoir host plants.

D.5 Inoculate/augment parasite and predator populations through propagation and release.

Results of release/augmentation approaches have been variable depending on the natural enemy being evaluated, the crop and environment into which it was released. The results overall have been judged encouraging.

D.6 Determine effects of pathogens on regulating SPW populations.

Beauveria bassiana and *Paecilomyces fumosoroseus* isolates from diverse geographic regions of North America and Asia were found highly effective against immature whiteflies in laboratory assays. Assays of selected isolates against the principal parasites and predators of whiteflies were initiated. Applications of oil-formulated *B. bassiana* and *P. fumosoroseus* produced highly variable levels of control in field and greenhouse trials. These initial results are promising, but indicate a need for much additional field testing of fungus formulations, including spray adjuvant controls.

D.7 Evaluate compatibility of pesticides with SPW natural enemies.

Cotton leaf residues of seven insecticides were tested for effects on four species of adult parasitoids. Buprofezin was non-toxic to all parasitoids; amitraz showed intermediate effects. *Eretmocerus mundus* from Spain exhibited some tolerance to the four insecticides.

D.8 Systematics of predators, parasites and pathogens.

Extensive survey material has been curated and identified. A protocol was established and agreed to by ARS, APHIS, and SAES scientists for vouchering of specimens from importations, centralized database for all importations established), databases established for *Encarsia* and *Eretmocerus* of world, several potential new species identified in U.S., crossing studies conducted on *Eretmocerus* and *strenua* and *parvella* groups of *Encarsia*.

E. Crop Management Systems and Host Plant Resistance

Chairs: D. D. Hardee and Ray Carruthers

INVESTIGATOR'S NAME(S): Kent D. Elsey, Mark W. Farnham, & Wilant van Giessen

AFFILIATION & LOCATION: USDA, ARS, U.S. Vegetable Laboratory, Charleston, SC

RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: 1993

GLOSSY BRASSICA'S RESISTANCE TO *B. TABACI*

In a screen cage test during the spring of 1993, broccoli (58 lines including one glossy and one with nonglandular trichomes), cauliflower (7 lines), collard (5 lines including two glossy), and kale (two lines, one glossy and one normal) were exposed to released *Bemisia tabaci* adults. At the vegetative/button stage of broccoli there were less than 1 adult and 3 nymphs /100 cm^2 on the glossy line Glazed Broccoli 3 compared to a standard broccoli mean of 11 adults and 150 nymphs / 100 cm^2. The hairy broccoli line (B8744) was heavily infested with 20 adults and 263 nymphs / 100 cm^2. Two glossy collard lines (Green Glaze & SC Glaze) had fewer whitefly adults and nymphs (4 and 24, 2 and <1 / 100 cm^2, respectively) at the late vegetative stage than the standard collard mean of 15 adults and 107 nymphs / 100 cm^2. A glossy kale Red Green Glaze had 10 adults and 31 nymphs / 100 cm^2 compared to 48 and 414 for the standard Vates kale.

We also found in three field tests that the glossy broccoli and collard lines mentioned above (plus Glazed Broccoli 5) had consistently lower numbers of *B. tabaci* adults and nymphs than nonglossy lines.

In clip cage experiments on potted plants the rates of increase for *B. tabaci* calculated from fecundity, survivability and developmental data was as high or higher on glossy broccoli and collards as that on nonglossy lines. Therefore, under those experimental conditions, antibiosis was not found to be a factor in explaining the resistance of glossy lines in the screen cage and field experiments.

INVESTIGATOR'S NAMES: Peter Ellsworth[1], Donna Meade, Steven Husman[2], Charles Ramsey[2], Jeff Silvertooth[3], and Joel Malcuit[3]

AFFILIATION & LOCATION: [1]University of Arizona, Maricopa Agricultural Center, Maricopa, AZ; [2]University of Arizona, Maricopa County Extension, Phoenix, AZ; [3]University of Arizona, Department of Plant Sciences, Tucson, AZ

RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: 1992-1993

SWEETPOTATO WHITEFLY PREFERENCE AND PERFORMANCE ON MEDIUM MATURITY COTTON VARIETIES IN ARIZONA

1992: In conjunction with the 1992 cotton variety testing program, 12 medium maturity varieties were evaluated for the presence of sweetpotato whiteflies (SPWF). Three sites (Queen Creek, Maricopa, Coolidge) were selected for expression of a full range of infestation intensity. Total immatures (eggs+nymphs) per square inch ranged from less than 8 to more than 800, depending on site, sample date and variety. Results indicated that there were significant effects of variety on SPWF numbers; however, the ranking of varieties was not always the same nor significant. Most varieties performed comparably, but one consistently had more SPWFs than the remaining varieties (cb1135). Comparative results from the three sites indicate that there may be separate preference and performance components which lead to the development of an infestation. Leaf hairiness was quantified from samples at one site, and the relationship of this factor to whitefly susceptibility was considered. Two varieties, cb1135 and stv453, were found to be significantly more hairy than the remaining varieties with the following ranking of decreasing hairiness: stv453 = cb1135 > Salcot10 = sgx1409 ≥ cb407 = dpl5461 = stv311 = dpl5415 = s1001 = hs46. Further analyses will attempt to relate various crop production and agronomic factors to SPWF susceptibility (e.g., plant height, fruit retention, height:node ratio, canopy closure, growth habit, maturity, yield, crop protection regimen). One fact was clear, however. None of the varieties evaluated here demonstrated resistance to SPWFs and certainly not to the extent that a producer could eliminate substantial risk of infestation through variety selection alone.

1993: Evaluations continued this year at one site (Maricopa) with some changes in the varieties studied. In particular, the four varieties sgx1409, salcot10, cb1135, and stv453 were replaced by 4 new varieties sg501, stvla887, cb1233, and hs44. Data are currently being analyzed.

INVESTIGATOR'S NAMES: Peter Ellsworth[1], Donna Meade[1], David Byrne[2], Jon Chernicky[3], Erich Draeger[2], and Roberta Gibson[1]

AFFILIATION & LOCATION: [1]University of Arizona, Maricopa Agricultural Center, Maricopa, AZ; [2]University of Arizona, Department of Entomology, Tucson, AZ; [3]Arid AgResearch Inc., Maricopa, AZ

RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: 1991--1993

PROGRESS ON THE USE OF TRAP CROPS FOR WHITEFLY SUPPRESSION

1991: A field study was conducted to evaluate the effectiveness of managed, volunteer *Physalis wrightii*, Gray [Wright groundcherry (WGC)] as a trap crop for sweetpotato whiteflies (SPWF) adjacent to cotton. This annual native weed grows readily from indigenous seed, is ubiquitous in irrigated Az agriculture, and is a preferred SPWF host. Aldicarb at 2 rates was used in the WGC for control of SPWF. Aldicarb treatment in the trap crop did significantly affect SPWF populations in comparison with untreated WGC ($P=0.000$). Differences in numbers of adults observed on the 2 hosts were not significant. The chemically treated trap crop did significantly protect the cotton from larger and rapidly developing SPWF populations when compared to the untreated check with no adjacent WGC.

1992: Early WGC establishment was variable and compromised by insufficient water which delayed canopy development. When coupled with intense SPWF movement following melon drydown the trap crop was overwhelmed. Several observations were made: 1) the WGC trap was insufficiently developed to protect the cotton, 2) the proximity of unmanaged melons increased SPWFs locally to numbers which could not be suppressed before reaching the cotton, 3) maintaining the melons in good condition (i.e., well-watered) effectively retained SPWFs in the melons until dry-down, 4) soil-applied aldicarb did accomplish some degree of control of SPWFs on the WGC, but was inadequate in the face of tremendous immigration of SPWF adults, 5) intense SPWF pressure ultimately killed the majority of young WGC plants, and 6) yield and quality of the adjacent, late-planted cotton were commercially unacceptable and judged to be virtually a total loss.

1993: Late planted cantaloupes were substituted for the WGC trap crop, and plots were enlarged. The IGR, buprofezin, was applied to the trap on a weekly basis to suppress SPWF populations while minimizing disruption of natural enemies. Data have yet to be analyzed, but the benefits of this system were not readily apparent and untreated cotton was unacceptably sticky.

INVESTIGATOR'S NAME(S): H. M. Flint, S. E. Naranjo, T. J. Henneberry, N. J. Parks

AFFILIATION & LOCATION: USDA-ARS-Western Cotton Research Laboratory, Phoenix, AZ

RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: March 1992 to present.

EFFECTS OF COTTON PLANT WATER STRESS ON INFESTATIONS BY THE SWEETPOTATO WHITEFLY

We have studied the effects of cotton plant water stress on the sweetpotato whitefly, *Bemisia tabaci* (Gennadius) for several seasons in central Arizona. Infestations of immature whiteflies were studied in surface-drip or furrow-irrigated field plots (8-12 rows x 10 m) of short staple cotton in 1988, 1991, and 1993. Three levels of irrigation designed to produce low, moderate, or high plant water stress (at the end of irrigation interval) were tested each year. The seasonal average numbers of immatures of the sweetpotato whitefly on fifth main stem node leaves were greater in biweekly furrow-irrigated than in drip-irrigated than in drip-irrigated plots in 1988 and 1993, but not in 1991. Plants irrigated biweekly with additional supplemental irrigations during mid-season or full season weekly irrigations had intermediate numbers of immatures. Deltapine 50 (DPL-50) had a similar density of leaf trichomes but half as many nymphs on leaves as DPL-77 in the 1991 test.

In 1992 we studied eggs and nymphs in 0.2-ha plots of Deltapine 50 and Stoneville 506 (ST-506) irrigated weekly or biweekly. Plant water stress, as measured by leaf water potential, was 13% greater at 14 days than at 7 days following irrigation. Leaves of ST-506 averaged 35% more eggs of the sweetpotato whitefly per gram of leaf tissue than leaves of DPL-50. Leaves of plants irrigated biweekly had 27% more eggs and 35% more nymphs per gram than plants irrigated weekly. Samples of lint from the two cultivars irrigated biweekly had 46% more reducing sugar than did lint from the cultivars irrigated weekly. The 1992 results indicate that the numbers of immature sweetpotato whitefly on cotton plants can be reduced by 47% and similarly the percentage of sugar in the lint by selecting a less susceptible cultivar and reducing plant water stress.

In 1993 we conducted a comparison of DPL-50 with Pima S-7, a commercial long-staple cotton, on 0.2-ha field plots. The irrigation treatments were weekly or biweekly. Unlike previous tests, we used 4 applications of insecticides to limit the numbers of whiteflies. There was an average 57% reduction in eggs and nymphs on leaves of plants that were watered weekly compared to biweekly. Pima S-7 had fewer eggs and nymphs than DPL-50. The numbers of adults counted in sticky pans and on the bottoms of leaves were in proportion to the immatures in the various treatments. These results indicate that differences in immatures on leaves due to irrigation treatments are due to selection of the water-stressed plants by adults.

Water management to reduce plant water stress is a useful tool in an integrated program to control whitefly infestations in cotton.

INVESTIGATOR'S NAME(S): H. J. McAuslane, F. A. Johnson & D. A. Knauft

AFFILIATION & LOCATION: University of Florida, IFAS, Gainesville, Florida

RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: June - November, 1993

EVALUATION OF PEANUT BREEDING LINES AND CULTIVARS FOR RESISTANCE TO SWEETPOTATO WHITEFLY

During the 1993 field season, 7 peanut breeding lines were evaluated for resistance to sweetpotato whitefly. A third and final year of data on resistance of 6 commercial peanut cultivars to whitefly was obtained.

Breeding lines - Peanuts were planted on June 3, 1993 on the campus of the University of Florida, Gainesville, FL. Ten treatments were replicated 4 times and planted in 2-row 6.1-m long plots. Treatments consisted of 4 pedigrees of 567A x GP NC 343, 3 pedigrees of 81206 x GP NC 343, GP NC 343, and Florunner and Southern Runner as controls. Plots were sampled at 10-day intervals from July 15 to October 4. Leaflets were picked randomly from the fourth fully expanded leaf from the top of 20 plants per replicate. Eggs and red eye nymphs (REN) were counted on top and bottom surfaces of each leaflet with the aid of a dissecting microscope.

Season average number of eggs per leaflet ranged from 3.04 to 1.02. All breeding lines had significantly more eggs than Florunner and Southern Runner, except for F1384 (one pedigree of 567A x GP NC 343). Season average number of REN per leaflet ranged from 0.312 to 0.086. Several lines had significantly more REN than the commercial cultivars but only F1384 had as few as Florunner.

Commercial cultivars - Six commercial cultivars (Southern Runner, Florunner, Sunrunner, AT 127, GK7 and Marc I) were planted on June 3 on the University of Florida campus. Treatments were planted in 4-row 6.1-m long plots replicated 8 times. Plots were sampled at 10-day intervals from July 20 until October 8. Samples were taken in the same way as those for the breeding lines. In the laboratory, we counted eggs, young instars (1st to 3rd), unparasitized 4th instars, parasitized 4th instars, and REN. Rates of parasitism are reported in McAuslane *et al.* (Section D, this book).

Eggs were most abundant on August 30. On this date, Southern Runner and AT 127 had significantly more eggs per leaflet than other cultivars. Young instars (1st to 3rd) were most abundant on September 8. AT 127 and Southern Runner again had the most young instars, although Southern Runner did not have significantly more than the next cultivar, GK 7. Numbers of unparasitized 4th instars peaked on September 17 and numbers of parasitized 4th instars on September 28. Southern Runner and GK 7 had significantly more unparasitized 4th instars than the other cultivars and Southern Runner had the most parasitized 4th instars. REN populations peaked 3 times but no significant differences among cultivars were found. Data from last field season indicated that Florunner was most infested and Southern Runner was least infested by whitefly. We conclude from this third year of data that there are no significant differences in resistance to sweetpotato whitefly among moderately-infested peanut cultivars grown commonly in Florida.

INVESTIGATOR'S NAME(S): J. D. McCreight[1], G. Elmstrom[2], A. M. Simmons[3], and D. Wolff[4].

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance.

DATES COVERED BY REPORT: August - October 1993.

MELON VARIETY TRIALS

A field study was conducted to evaluate the response of selected cantaloupe varieties in four locations, California, Florida, South Carolina, and Texas, to *Bemisia tabaci*. From each location, a commercially grown variety was selected for testing and included 'Top Mark,' 'Primo,' 'Mainstream,' and 'Perlita'). All varieties were evaluated at each location. Each week, half of each plot of a given variety was treated with insecticide as a check. Weekly data were obtained on number of adult whiteflies. At 4 and 8 weeks, data were obtained on egg and nymphal whitefly counts, plant biomass, vine growth, plant condition rating, and leaf area. The data are being summarized.

INVESTIGATOR'S NAME(S): Eric T. Natwick

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: April through September 1993

COTTON CULTIVAR EVALUATION FOR SUSCEPTIBILITY TO COLONIZATION BY THE SILVERLEAF WHITEFLY

Several cotton cultivars including an okra leaf cultivar were planted at the University of California Imperial Valley Research and Extension Center. Insecticide treatments using Monitor® plus Baythroid® were applied to each variety weekly from June 22 to August 10 in an attempt to keep whitefly nymphal populations below a threshold of 10 nymphs/cm^2 on the sixth main stem leaf below the terminus. Cultivars included CB1233, CB1135, CB232, CB333, DP50, DP90, DP5415, DP5461 and Siokra.

Whitefly sampling consisted of extracting leaves from cotton plants selected at random. Leaves extracted were from the main stem at the eighth, sixth and fourth positions below the terminus, dependent upon the location of nymphs and availability of leaves for sampling. Using a binocular microscope, the total number of eggs and nymphs were recorded from two 1.25 cm^2 discs for each leaf. Leaf samples were extracted weekly from June 1 to August 13, 1993. Seed cotton was mechanically harvested September 9 and 10, from each plot, weighed, and seed cotton yield per acre was calculated.

On the June 1 pre-treatment sample DP 90 had the lowest egg mean of 0.5 per cm^2 followed by DP 50, CB 333, and DP 90 each 0.6 eggs per cm^2 which were significantly lower ($P = 0.05$) than CB 1135, DP 5461, and Siokra with egg means of 1.7, 1.4, 1.9, respectively. During the following two pre-treatment samples, DP 50 (22.8) and CB 333 (33.9) egg means increased dramatically and were significantly greater than DP 5415 (6.3) on June 18. Siokra had the second lowest egg mean (11.8) on June 18 which was significantly lower than CB 333 (33.9). Following the Monitor® 4/Baythroid® 2EC treatments Siokra and DP 5415 had the lowest egg means while DP 50 and CB 333 had the highest egg means. The cultivars CB 333 and CB 1135 had the greatest nymph means on the three pre-treatment sampling dates and DP 5415 had the smallest means on the same dates. On June 18, CB 333 and CB 1135 had nymph means of 3.4 and 2.8 per cm^2, respectively, which were significantly greater than the means for all other cultivars. After Monitor® 4/Baythroid® 2EC treatments were initiated CB 333, DP 50, and CB 1135 usually had the largest nymph means and Siokra and DP 5415 had the lowest nymph means. The seed cotton mean for DP 5415 was significantly greater than all other cultivars with a mean of 1152.38 pounds per acre, which was consistent with the relatively low whitefly population level as compared to all other cultivars except Siokra which was the fourth greatest with 771.28 pounds per acre. The cultivars DP 5461, CB 1135, and CB 333 all had high whitefly means on post-treatment sampling dates and resulted in the lowest seed cotton yields at 521.75, 589.80, and 612.49, respectively. The third greatest seed cotton yield was 789.43 pounds per acre from DP 50, in spite of high whitefly densities.

INVESTIGATOR'S NAME(S): Eric T. Natwick, Keith S. Mayberry and Franklin F. Laemmlen

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: March through June 1992

PROTECTION FROM PHYTOPHAGOUS INSECTS IN CANTALOUPE MELONS USING ROWCOVERS, REFLECTIVE MULCHES AND REFLECTIVE NETTING

A planting of cantaloupe (Asgrow var. Topmark) was established at the University of California Desert Research and Extension Center near Holtville, California. Reflective mulch treatments were placed over beds of 60 inch centers March 11, 1992. Melons were hand planted into holes cut in the mulch at one foot intervals. All other treatments were mechanically planted. Five rowcover treatments were planted into mid-bed trenches one foot deep and 15 inches wide at the top. Mid-bed trench rowcover treatments included: Vispore® X-6576, Vispore® X-6578, Agribond®, Agribond followed by Polynet IPM Barrier cover at bloom when the Agribond was removed, and Agryl® P17. The reflective bed-mulches were 48 gauge silver metalized polyester from JSC Machinery and supplies and a silver/gray bed-mulch from Scharr Industries, Inc. Agribond was also placed over beds without the mid-bed trench as a floating rowcover. Including the control (bare beds) there were nine treatments with 4 replications in a randomized complete block design. All plots were irrigated by furrow on March 13-15, 1992 to germinate the melon seed. Plots measured 10 feet by 50 feet.

Plant height in centimeters, the number of true leaves per plant, the number of melon aphids (*Aphis gossypii*), the number of adult silverleaf whitefly (*Bemisia* n. sp.), the number of western flower thrips (*Frankliniella occidentalis*), and the number of vegetable leafminer (*Liriomyza sativae*) per plant were sampled on five plants in each plot April 6, 1992. Adult silverleaf whitefly were again counted on five plants per plot April 27, 1993. Silverleaf whitefly damage ratings were determined for each plot June 12, 1992.

All mid-bed trench rowcover treatments produced larger plants earlier in the growing season, compared to the control and reflective mulches. Melon aphids were completely excluded by rowcover treatments. The reflective mulch and control treatments were infested with melon aphid. Mid-bed trench rowcover treatments completely excluded, and the floating rowcover nearly excluded all silverleaf whitefly from planting until removal of covers for pollination, other treatments were heavily infested. The control and floating rowcover treatments had much greater western flower thrips infestation than mid-bed trench treatments. The vegetable leafminer infestation was significantly greater in the bare ground control as compared to all other treatments. On April 6, the Agryl P17 mid-bed trench treatment had the most leaves and plants were 12.48 cm in height significantly ($P = 0.05$) taller than all but Vispore X-6578, Vispore 6576 and Agribond mid-bed trench treatments. The control plant height was 4.0 cm.

INVESTIGATOR'S NAME(S): Eric T. Natwick and Keith S. Mayberry

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: September 1992 through March 1992

EVALUATION OF REPELLENTS OF SILVERLEAF WHITEFLY ON ICEBERG LETTUCE

Three plastic bed mulch cover treatments were applied over lettuce beds and holes were cut for direct seeding. The bed mulch treatments included an aluminum coated plastic, a white reflective plastic and a silver colored reflective plastic all developed as insect repellent materials. Jojoba liquid wax, Rodspray (mineral oil), Gardian spray (garlic water) and Melaluca (an extract from eucalyptus) were sprayed on lettuce as repellents.

Repellency from plant extracts and the oil spray used in the experiment did not adequately protect iceberg lettuce from silverleaf whitefly. The reflective mulches did repel some adult whitefly, but they were also not efficacious enough to justify their use by growers considering the expense of materials, application and removal costs.

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: January 1993 - December 1993

SUSCEPTIBILITY OF MELON CULTIVARS TO WHITEFLIES

Selected melon cultivars were planted in 80" beds in treated and untreated field plots for the control of the b-strain sweetpotato whitefly (SPWF) in February 1993. Treatments were arranged in a split plot design with insecticide treatment as the whole plot and cultivars as the subplot. SPWF adults were sampled weekly on whole leaves at the 3rd node from the growing point and immature SPWF were sampled from two leaf disks per leaf (total 7.6 cm^2 of leaf area) sampled at the 6th node from the growing point. Sample size was five leaves per plot for adult counts and ten leaves per plot for nymph counts. Whitefly ovipositional preference and plant tolerance were evaluated by monitoring SPWF numbers and plant yield response. Plant damage ratings included sooty mold, reduction of plant vigor, and the occurrence of other plant diseases. Yield was evaluated in terms of total harvested weight, number of boxes, and average size class. Harvested melons were separated by size class for weight and volume determinations and yield weight is reported by size class and as totals.

Tam Sun, HMX 9583, and Explorer were associated with moderate SPWF numbers, but provided the greatest yield and harvested dollar value. Cultivars that responded significantly to whitefly control included Otero, Caravelle, Perlita, Tasty Sweet, Tam Sun, HMX 9583, D21-1005, Tam Uvalde and Mainpak. Tam Mild Sweet 89 appeared to be the most preferred by whitefly adults.

INVESTIGATOR'S NAME(S): D. J. Schuster, J. W. Scott, C. R. Thome, J. E. Polston

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance

DATES COVERED BY REPORT: September 1992 - December 1993

HOST PLANT RESISTANCE FOR MANAGEMENT OF THE SWEETPOTATO WHITEFLY AND TOMATO MOTTLE GEMINIVIRUS ON TOMATO

Ten accessions of *Lycopersicon hirsutum* and *L. pennellii* were evaluated in the laboratory for their impact on the sweetpotato whitefly. Not all of the accessions within a species responded similarly to the whitefly. The highest adult mortality and lowest oviposition occurred on the *L. hirsutum* accessions LA1777, LA1927 and LA1772 and the *L. pennellii* accession LA716.

Trichome counts and a modified stickiness test were found unacceptable for screening *L. esculentum* X *L. pennellii* germplasm in the seedling stage for resistance to the sweetpotato whitefly. The modified stickiness test was found acceptable for screening germplasm in the field but was found to be affected by age of leaf, by side of plant evaluated, and by the presence of tomato mottle geminivirus (TMoV) symptoms.

An F_3 population varying widely in stickiness, was evaluated in the field and indicated that stickiness and acyl sugars were negatively correlated with sweetpotato whitefly feeding and oviposition, and positively correlated with days to TMoV acquisition.

Eight F_4, five $F_3BC_2F_2$, and 30 F_5 families were evaluated for resistance to the sweetpotato whitefly in the field. Of about 350 plants evaluated for stickiness and horticultural traits, 52 were selected for low TMoV symptom expression, high stickiness, and fruit-set.

TMoV inoculation of seedlings using viruliferous sweetpotato whitefly adults confined either on individual plants using clip cages or on groups of plants in styrofoam trays was unsatisfactory. A method using viruliferous sweetpotato whitefly adults released into small, insect-proof greenhouses was used successfully for screening 7,800 seedlings from 275 breeding lines. The lines were derived from 7 L. chilense accessions and were in $F_1BC_1S_1$, $F_1BC_1S_2$, or F_1BC_2 generations. About 2,700 plants were transplanted to the field and 276 selections were made for TMoV tolerance.

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance.

DATES COVERED BY REPORT: April - November 1993.

BREEDING MELONS FOR RESISTANCE

Greenhouse studies were conducted to develop rapid, reproducible techniques for breeding germplasm of melon (*Cucumis melo* L) for resistance to *Bemisia tabaci*. The plant response of 23 selected lines to the sweetpotato whitefly was studied in the greenhouse. The research was focused on western type cantaloupes, although one eastern cultivar was used for comparison.

The melons were planted in a greenhouse section containing a colony of an unknown number of sweetpotato whitefly being reared on 10 vegetable crops. Plants were harvested two weeks after plant emergence. Data were collected on fresh and dry biomass of roots, leaves, stems, and number of immature sweetpotato whitefly. Moreover, data on root and stem length and stem diameter were obtained. Additional seeds of each treatment were planted in a 'whitefly-free' greenhouse section under similar conditions as the infested section. The melon plants varied in leaf area. Thus, whitefly counts were compared among plants when expressed on a per leaf area basis.

Among six parents, 'Snakemelon' had the lowest whitefly count/unit leaf area as well as the highest plant quality rating. Five of the crosses had whitefly counts/unit area that were lower than 'Snakemelon.' Four of these had plant quality ratings higher than 'snakemelon.' Moreover, the ratings for these plants were among the highest evaluated. There was good correlation between whitefly/unit leaf area and plant rating data. Weight data were complementary, but were not as consistent.

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RESEARCH & IMPLEMENTATION AREA: Section E: Crop Management Systems and Host Plant Resistance.

DATES COVERED BY REPORT: January 1993 - December 1993.

PLANT BIOCHEMICAL REGULATORS (PBRS) TO MEDIATE INTERACTIONS OF THE SWEETPOTATO WHITEFLY

For the past two years, we have been using plant biochemical regulators (PBRs) to mediate interactions of the sweetpotato whitefly (SPW) with its host plant. Two approaches were pursued in these experiments: (1) use of gibberellic acid inhibitors such as Cycocel (CCC) to simulate induction of leaf silvering symptoms in cucurbits to determine etiology of whitefly-induced squash silverleaf (SSL); and (2) use of certain PBRs to ameliorate the damage caused by the SPW through host modification or induction of resistance factors in tomatoes, cucurbits, and other vegetable crops.

CCC induced leaf silvering in Cucurbita pepo cv. small sugar pumpkin leaves that emerged 3 days after application, similar to the time observed for SPW-induced SSL. CCC increased chlorophyll content, whereas chlorophyll was reduced in SPW-mediated SSL. Paclobutrazol (PZ) induced leaf silvering similar to CCC, but Alar did not. Foliar application of Pro-Gibb 4% immediately following CCC or PZ treatment attenuated internodal shortening and eliminated leaf silvering symptoms. We concluded that PBR-induced leaf silvering and SPW-induced SSL result from plant hormonal-mediated alterations in growth and development. Experiments are continuing to further elucidate the mechanism of leaf silvering in efforts to determine mode of action of the putative toxicogenic factor associated with SPW-B.

SPW egg counts tended to be higher on CCC-treated cucurbits than on non-sprayed controls in experiments conducted in cages and on the open bench in the greenhouse. In field trials, egg deposition and nymphal counts were lower in CCC-treated plots than non-sprayed controls. These results are preliminary and experiments are continuing.

In preliminary shadehouse trials where container-grown tomatoes were treated with FVCL-2, imidacloprid, and CCC, the experimental compound imidacloprid was superior in SPW control and resulted in higher number of fruit and fruit weight than other treatments. Only CCC caused detectable phytotoxicity with the marginal scorching of treated leaves. This was offset by the production of a more horticulturally manageable plant. SPW counts on CCC-treated plants were lower than that of the water spray control. Imidacloprid and CCC treatment resulted in slightly higher fruit yields and a tendency for earlier maturation. Experiments are continuing.

TABLE E. Summary of Research Progress for Section E - Crop Management Systems and Host Plant Resistance, in Relation to Years 1 and 2 Goals of the 5 Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
E.1 Determine effect of traditional crop production inputs on SPW population development.	Yr. 2: Identify crop production methodology that may be a factor in SPW population development.	X		Additional research was conducted on the use of irrigation/water stress on SPWF populations. Both patterns of irrigation (weekly vs. bi-weekly) and overall volume of water applied affected pest levels. Water stressed plants received more SPWF eggs than non-stressed plants. Sprinkler irrigation was found to reduce SPWF populations over adjacent furrow irrigated areas. Plant biochemical regulators were also used to mediate interactions between SPWF attack on several different host plants.
E.2 Determine temporal and spatial effects of host plants on SPW populations and dispersion.	Yr. 2: Identify preferred cultivated and weed hosts and contribution to overall population density and SPW dispersion.	X		Progress was achieved in identifying differences within and between cultivated crops to attack by SPWF, including cultivar differences within species of vegetables and cotton. Smooth leaf species/varieties showed less SPWF numbers than hairy leaf varieties. Phenological differences in the timing of insect attack on different crops and their spatial arrangement have allowed cultural practices such as planting times, harvest dates, crop residue destruction, etc., to be manipulated to reduce damage in some production areas.
E.3 Determine effect of colored mulches, trap crops, intercropping, row covers, and other innovative cultural practices as potential SPW control methods.	Yr. 2: Determine potential effectiveness of innovative cultural practices on SPW behavior.	X		Row covers were found to be effective in limiting SPWF infestations on cantaloupe through the early season, until their removal for pollination. Other insect pest problems, particularly aphid damage, were also highly reduced using row covers. Plastic mulch covers (white and silver reflective materials) did repel some SPWF adults but were not efficacious enough to justify their use.
E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.	Yr. 2: Apply develop methodology to identify resistant germplasm.	X		A variety of methods were developed and used to assess host plant resistance levels associated with SPWF attack. Studies were conducted on cole crops (broccoli, cauliflower, collards and kale), melons, peanuts, and cotton. Interactions of SPWF and gemini viruses were jointly evaluated for resistance in tomatoes. In the tomato tests, 7800 seedlings from 275 breeding lines were evaluated. First level screens identified 2700 plants for field testing. Approximately 275 selections were made for tomato mottle gemini virus.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
E.5 Identify resistant germplasm to SPW and associated viruses and plant disorders.	Yr. 2: Screen and identify resistance sources.	X		High levels of resistance to SPWF were not found in any crop species or cultivars tested. Some crops such as peanuts, showed no significant differences in susceptibility of tested cultivars to SPWF attack. In melons, cotton, and some other crops, differences between cultivars were clearly noted although none were able to withstand high SPWF pressure during susceptible stages of development. It was felt by the overall research group that host plant resistance was not a likely short-term solution to the SPWF problem in cotton, and should be deemphasized though in the final years of this effort while long-term efforts should be continued through established breeding programs.
E.6 Conduct plant breeding studies to select SPW resistant plant germplasm.	Year 2: Apply and develop methodology to identify resistant germ-plasm.	X		Breeding lines were investigated for both melons and tomatoes. Snakemelon was identified as a parental material that had low SPWF counts/unit area. Several crosses with this material produced lines that had fewer SPWF counts than the snakemelon. Of an extensive number of tomato lines evaluated for stickiness and horticultural traits, 52 were selected for low tomato mottle virus symptom expression, high stickiness and fruit-set. Selection studies are continuing along lines of positive response.

RESEARCH SUMMARY

Section E: Crop Management Systems and Host Plant Resistance

Compiled by
D. D. Hardee and R. I. Carruthers

E.1 Determine effect of traditional crop production inputs on SPWF population development.

Irrigation studies conducted in California and Arizona revealed that both overhead and furrow irrigation lowered damage from SPWF attack. Sprinkler irrigation limited SPWF populations by dislodging adults from the plants, thus increasing mortality and decreasing oviposition. Oviposition on drought stressed cotton (controlled by furrow or drip irrigation) was found to be approximately double that on unstressed cotton plants. By changing the distribution of a fixed amount of water (weekly vs. biweekly irrigation) or by increasing the amount of water provided to the plants, SPWF damage was reduced. This research has shown now for three consecutive years that management of plant water stress is a useful tool that can be incorporated into integrated pest/crop management programs.

Plant biochemical regulators have been used in the field to help determine the etiology of whitefly-induced squash silverleaf (SSL) and also evaluated as production tools that may limit SPWF populations in some crops. Applications of Cycocel or Paclobutrazol induce SSL and have helped determine that SPWF-induced silvering results from plant hormonal-mediated alterations in growth and development. Shadehouse trials of container-grown tomatoes treated with FVCL-2, imidacloprid, and Cycocel revealed that imidacloprid was superior in SPWF control and resulted in more fruit, higher fruit weight, and earlier maturity. Studies on plant biochemical regulators are continuing.

E.2 Determine temporal and spatial effects of host plants on SPWF populations and dispersion.

SPWF management and extension groups in several areas of the country have developed crop residue management and crop planting schemes based on insect population and dispersion characteristics. In the Lower Rio Grande Valley of Texas, for example, an area wide sampling program is conducted throughout the year, and is used to advise farmers and other agricultural production managers of SPWF activity across both time and area. Advisories have successfully been made to limit planting adjacent to infested areas, to destroy crop residue as soon as possible after harvest, and to avoid planting until after major SPWF dispersal following cotton defoliation in the late summer. Linkage of these practices with regional spatial models is being conducted in cooperation with Section E and is based on the use of satellite imagery, computer assessments of infested fields, and knowledge associated with SPWF migration developed from research conducted in Section B.

E.3 Determine effects of colored mulches, trap crops, intercropping, row covers, and other innovative cultural practices as SPWF control methods.

Row covers were found to be extremely effective in limiting SPWF infestations during the portion of the season when these barriers can be deployed over crop seedlings. In addition, rowcovers were also effective in limiting aphid populations on young melons. Control was adequate in field tests until the rowcovers were removed for pollination, while other treatments were heavily infested. Although rowcovers are used by some producers to protect seedlings from insects and early frost damage, the economics of this practice may limit its application to some crops and locations. Artificial plastic mulches were also tested in several situations and found to provide some level of protection to SPWF infestations but not at sufficient levels to justify their use in commercial situations. Natural products such as jojoba liquid, rodspray (mineral oil),

gardian spray (garlic water) and melaluca (an extract from eucalyptus) did not adequately protect lettuce from SPWF attack.

E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.

Methods were developed and used to evaluate a variety of crops for resistance to SPWF and gemini-viruses. Studies were conducted on cole crops (broccoli, cabbage, cauliflower, collards and kale), cotton, melons peanuts, and tomatoes. Some techniques were developed primarily to conduct screening of existing cultivars while others were developed to explore lines of germplasm from wild/non-cultivated hosts. Specific methods were developed for individual crop species and included tests ranging from determining ovipositional activity to tolerance of attack through non-expression of symptoms.

E.5 Identify resistant germplasm to SPWF and associated viruses and plant disorders.

Although studies were conducted in several different crop species, high levels of resistance to SPWF-induced damage was not found. Some differences in susceptibility between different cultivars in a wide variety of crops was noted; however, they provided limited protection from damage, particularly in areas of severe infestation. Overall, it is thought that the development of resistant varieties for most crops is a longterm project that is best conducted through conventional breeding programs supported through commercial interests, state universities and grower organizations. It was suggested at the annual meeting that rather than direct additional resources into the development of SPWF resistance, that efforts should be focused on resistance to gemini-viruses associated with SPWF transmission.

E.6 Conduct plant breeding studies to select SPWF resistant plant germplasm.

In some areas such as melons and tomatoes, crop breeding lines have been identified where some levels of resistance to SPWF-induced damage is available. In melons, parental snakemelons provided increased levels of resistance (measured as lower larval populations) in crosses with other germplasm, when compared to susceptible varieties. Although this factor may not be true resistance and only preference, further breeding and testing are required to determine the potential of these materials. The same is true in association with tomato breeding lines where over 7,800 seedlings from 275 different breeding lines have been evaluated. Following greenhouse screening, 2,700 plants were transplanted to the field where over 200 selections were made for tolerance to tomato mottle geminivirus.

F. Integrated Techniques, Approaches, and Philosophies

Chairs: Jose M. Amador and Donald Nordlund

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RESEARCH & IMPLEMENTATION AREA: Section F: Integrated Techniques, Approaches and Philosophies

DATES COVERED BY REPORT: July 1, 1993 to present

MODELING OF THE MOVEMENT AND REPRODUCTION OF THE SWEETPOTATO WHITEFLY

We are developing models of the movement and reproduction of sweetpotato whitefly (SPW) (aka the silverleaf whitefly) on a scale of 1-100 miles in regional cropping systems. We construct crop maps by two methods: 1) experimental maps of any sort in which we vary the scale, diversity, spatial pattern, type and orientation in relation to prevailing wind, and 2) actual maps constructed from LANDSAT satellite images. Simulation using these maps will help to identify crop patterns which reduce the levels of SPW.

Movement of SPW in crop systems is apparently of two major types: 1) short-range diffusive movement (1-100m), and 2) long-range migratory movement (1-5km). Both types of movement are strongly affected by wind. Diffusive movement is fairly continuous and relatively independent of crop condition. As a crop sceneses, however, plant cues cause the development of a "migratory type" of SPW. These migratory adults fly at dawn during light wind conditions (2-5mph) and can drift for several kilometers to settle on another crop. (This information provided by D. Byrne, University of Arizona).

We are using two sources of data on SPW movement. The first is georeferenced sampling of the ongoing SPW invasion in the San Joaquin Valley in California in cooperation with C. G. Summers (Kearney Ag. Center, U. C. Davis). Foci of infestation have been followed for over one year, and SPW has spread over 15 miles downwind from the original infestation sites. Additional studies of D. Byrne in Arizona using SPW marked with flourescent dust are being used to help estimate movement rates for the model.

Crop maps of existing agroecosystems in SPW problem areas are being constructed from LANDSAT satellite images with the help of Jack Paris (Cal. State Univ., Fresno, CA). A sequence of 4 LANDSAT scenes on the SPW invasion area is being used to construct the crop map in relation to SPW movement. We will also construct crop maps of Imperial Valley, CA, Lower Rio Grand Valley, TX, and south Florida for comparison of crop systems. Additional SPW field data is being provided by T. M. Perring U. C. Riverside, D. R. Riley, TAMU, and P. A. Stansly and D. J. Schuster, University of Florida.

An IBM-compatible knowledge-base program (WHITEFLY) on the SPW is also under construction by T. R. Fasulo (University of Florida) and this work is being coordinated with the "hard-copy" information booklet being developed by the "SWAT" project.

We would like to acknowledge the USDA NAPIAP Program for making this project possible.

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RESEARCH & IMPLEMENTATION AREA: Section F: Integrated Techniques, Approaches and Philosophies

DATES COVERED BY REPORT: 1993

ORGANIZATION OF COMMUNITY-WIDE IPM IN COTTON

An extension supported, grower controlled, community pest management group was initiated in the Laveen and Tolleson communities of Arizona with the management of sweetpotato whitefly (SPWF) as its initial focus. The three functions of this group were awareness, communication, and cooperation. Increased awareness and communication of pest management problems and solutions were achieved through regular meetings and newsletters. Community cooperation took the form of a community-based overwintering survey and a sticky trap network. These two cooperative activities served both an educational and a research function. From the overwintering survey and the sticky trap network, growers learned about the overwintering habits and movement dynamics of whiteflies in their area, the limits of sticky traps for SPWF detection, the need for the reduction of SPWF populations before they move onto cotton, and the importance of careful infield sampling of SPWF populations.

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RESEARCH & IMPLEMENTATION AREA: Section F: Integrated Techniques, Approaches and Philosophies.

DATES COVERED BY REPORT: 1/93-12/93.

COORDINATING WHITEFLY EXTENSION ACTIVITIES IN THE SAN JOAQUIN VALLEY

A coordinated extension effort was undertaken to provide educational outreach for and situation analysis about Silverleaf whitefly in the San Joaquin Valley (SJV). The purpose was to provide a structure for coordination of activities and information among the private sector and public agencies involved in whitefly issues.

Silverleaf Whitefly Management Committee. In March of 1993, invitations were sent to representatives of key commodities, individual producers and Pest Control Advisors (PCAs). The purpose of the meeting was to provide an opportunity to discuss the establishment of a management committee similar to that of Imperial County. SJV growers and allied industry were reluctant to form a similar committee but wanted the various research, extension, and regulatory agencies to continue meeting monthly, to follow the whitefly situation closely, and to keep the industry informed.

The monthly meetings brought together representatives of the major commodity groups, PCAs, agrichemical industry, and public agencies. Public agencies included California Department of Food and Agriculture, County Agricultural Commissioners, UC Experiment Station, and Cooperative Extension. Both agricultural and urban interests were represented.

Telephone Hotline and Computer Bulletin Board. A toll free telephone line (800 880-0981) was established to provide timely whitefly situation reports. In an effort to improve the interactive capabilities of the system, callers were given the opportunity to leave information if they desired. The hotline received 250 calls between July and September.

A computer bulletin board system (BBS) (209 646-3958) was established to provide a similar service but had the advantage of allowing for a season review of reports. Again, interactivity was encouraged through the development of forums in which users could leave information about the whitefly situation. In addition, text information, such as lengthy reports or reference material, could be stored for retrieval by the user. There are currently 18 users.

Educational Resources Developed During 1993. A general slide set was compiled by Godfrey and Goodell and distributed to county based extension advisors. An intensive training course is under development to expand the network of people providing general whitefly information to the public. Several pamphlets and fact sheets were developed and requests for copies can be made to lead author.

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RESEARCH & IMPLEMENTATION AREA: Section F: Integrated Techniques, Approaches and Philosophies

DATES COVERED BY REPORT: March 1993-November 1993

OBJECT-ORIENTED SIMULATION MODELING IN THE BIOLOGICAL CONTROL OF *BEMISIA TABACI*

The HERMES (Hierarchical Environment for Research Modeling of Ecological Systems) modeling environment was developed at the USDA-ARS for the purposes of creating detailed, mechanistic models using pre-designed computational components ideally suited for simulating biological systems. Models are created by linking and manipulating graphical icons which represent the computational components. The simplicity of the Graphical User Interface and the hierarchical representation of the models allow non-programmers a unique tool with which to create models of arbitrary complexity.

We are currently using HERMES for modeling the interactions between *Bemisia tabaci* and two of its natural enemies: the autoparasitoid *Encarsia pergandiella* and the fungal pathogen *Paecilomyces fumosoroseus*. Because male *E. pergandiella* develop as hyperparasitoids of females of other immature parasitoids, often of their own species, theory predicts a stable host-parasitoid interaction. The model predicts an attack rate using a Type II functional response applied to the pooled primary and secondary hosts. The attack rate is partitioned between the two host populations by multiplying the rate by the ratio of primary or secondary hosts present. Thus, we assume that attack rate is a function of abundance of primary or secondary hosts. Several runs were performed using different values for a' and handling time, all of which predicted a stable equilibrium. In contrast, the removal of the autoparasitism component by allowing the parasitoids to attack only the whitefly produced severe fluctuations in the densities of both the whitefly and *E. pergandiella*. Simulations are currently being run to assess the ability of autoparasitoids to compete against normal primary parasitoids. An eventual objective of this study is to determine the possible role of autoparasitoids in biological control of the sweetpotato whitefly including the effect of male hyperparasitism on the host-parasitoid complex, and how autoparasitoids may be successfully incorporated with primary parasitoids in biological control programs.

Modeling the fungal pathogen *P. fumosoroseus* and its effect on the whitefly population includes assessing the influence of environmental factors such as temperature, humidity or solar radiation on both fungal and insect populations, and their interactions. The development of healthy and diseased whiteflies is simulated using the 2-dimensional time varying distributed delay, a HERMES component specifically designed to model disease. Laboratory data are being collected to provide parameter values for certain components of the model such as developmental times required for germination at different temperatures. Percentage germination is recorded at different times ranging from 4 to 24 hours. Laboratory data and simulation results are in close agreement using a delay time of 10 hours at 25°C. The long-term objective of this modeling effort is to simulate the process of fungal infection in order to optimize the use of pathogens as control agents of *B. tabaci*.

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RESEARCH & IMPLEMENTATION AREA: Section B: Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Vector Interactions

DATES COVERED BY REPORT: 1993

MOLECULAR CHARACTERIZATION AND COMPARISON OF COTTON LEAF CRUMPLE AND COTTON LEAF CURL GEMINIVIRUSES

Cotton leaf crumple virus (CLCV) and Cotton leaf curl virus (CLCuV) are whitefly-transmitted geminiviruses. CLCV mainly occurs in the US while CLCuV has been reported in Pakistan, Sudan and other countries. Infections by these geminiviruses early in the growing season can cause yield losses up to 70%. Geminivirus genomes consist of single-stranded DNA molecules. Total nucleic acids were extracted from CLCV and CLCuV infected cotton leaves. CLCV and CLCuV DNA was amplified by polymerase chain reaction (PCR) using degenerate oligonucleotide primers and subsequently cloned. The primers were designed based on the conserved regions of known geminivirus sequences. Analysis of the PCR products showed that CLCV DNA A is approximately 2.6 kb and CLCuV DNA A is approximately 2.7 kb. The PCR DNA from both viruses were hybridized with reciprocal probes. Both probes hybridized strongly with homologous DNA and differentially with heterologous DNA. These results indicate that CLCV and CLCuV are related but different geminiviruses.

The complete CLCV DNA A and partial CLCuV DNA A were sequenced. Sequence analysis showed CLCV DNA A contained four open reading frames (ORF) (AL1, AL2, AL3, and AR1) conserved among all subgroup III geminiviruses. In addition, several small ORFs on the viral strand and complementary strand were also predicted. Preliminary sequence analysis of CLCV and CLCuV DNA indicated that these two viruses are very distantly related. CLCV is more closely related to bean dwarf mosaic virus, squash leaf curl virus, potato yellow mosaic virus, Abutilon mosaic virus, and tomato mottle virus, while CLCuV is more closely related to cassa latent virus, African cassava mosaic virus, Indian cassava mosaic virus, and tomato yellow leaf curl virus. Among all whitefly transmitted geminiviruses compared, CLCV and CLCuV are most distantly related.

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RESEARCH & IMPLEMENTATION: Section F: Integrated Techniques, Approaches and Philosophies

DATES COVERED BY THE REPORT: 1993.

GEOSTATISTICAL ANALYSIS OF THE REGIONAL DISTRIBUTION OF VIRUSES TRANSMITTED BY THE SWEET POTATO WHITEFLY

1. Management strategies for tomato virus complex: Del Fuerte Valley, Sinaloa, Mexico.

Objective: Virus management plan for tomato processing industry.

The gemini viruses continue to be the principal component of the eight virus, three vector complex. Campbell Soup has changed locations and planting dates of tomato fields and increased alternate host control to avoid and prevent early season virus infection. GIS/geostatistical analysis of the virus epidemics has allowed us to estimate risk of virus infection for different areas of the valley and define landscape features conducive to virus occurrence and spread. During this project, Campbell's use of insecticides has gone from approximately 22,000 lbs. in 1988 to 0 in 1993 on the 2000 hectares of tomatoes they grow or contract. A large proportion of these insecticides were futilely directed at virus/vector control. The whitefly is not considered to be directly damaging to tomatoes in this area.

2. Epidemiology of cotton leaf crumple virus (CLCV) in Arizona.

Objective: Identify landscape features that are conducive to virus spread and quantify whitefly populations with virus distribution.

Spatial patterns in weekly whitefly data from 1000 locations in Arizona are analyzed in five kilometer blocks by kriging. Distribution of fields with virus infected plants does not show any consistent quantitative relationship with whitefly populations. Leaf crumple virus infection is found primarily in Maricopa, Pinal and Yuma counties. Within areas, virus distribution shows some relationship to border areas near river systems or other native landscapes. Leaf crumple causes major damage annually in a few fields often near spring cantaloupe plantings. Most other infections occur in mid season and are only moderately damaging. Direct whitefly damage is the major problem for Arizona cotton.

3. Cotton leaf curl virus (CLCuV) in Pakistan.

Objective: Determine if spatial structure of cotton leaf curl epidemics exists in Pakistan.

Spatial distribution patterns were obvious when virus data from seventy cotton fields in the Multan district of Punjab State, Pakistan was block kriged. The location of the fields was plotted on a digitized ARCINFO map using map coordinates obtained with a GPS unit (Ensign, Trimble Navigation Co.). Present in the fields were both leaf curl and leaf crumple symptoms.

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RESEARCH & IMPLEMENTATION AREA: Section F: Integrated Techniques, Approaches and Philosophies

DATES COVERED BY REPORT: September 1992 - December 1993

EVALUATION OF CROP ASSOCIATIONS FOR MANAGEMENT OF THE SWEETPOTATO WHITEFLY

Intensive sampling at an organic farm site was initiated for the sweetpotato whitefly in September 1992 on tomato, pepper, squash, cucumber and eggplant. Each commodity planting was subdivided into cells 100 feet long by 3 or 4 rows wide. A weekly sample was taken from each cell by counting the number of whitefly adults dislodged from the upper foliage of five plants and trapped in a thin layer of vegetable oil on the bottom of a black aluminum pan. Every two weeks, five leaves from each cell were collected and were held in paper cartons in a laboratory for emergence of sweetpotato whitefly and parasite adults. The numbers and identity of parasites are being determined. The data have been entered into a computer and have been graphed over time. The results illustrate the variation in sweetpotato whitefly populations spatially and temporally and by commodity. The data are being used to develop a mathematical model describing the buildup and movement of the sweetpotato whitefly among commodities. The data are being analyzed further to study the interactions among the commodities.

Squash is being investigated as a potential trap crop for the sweetpotato whitefly on tomato. In replicated field trials at the Gulf Coast Research & Education Center, more sweetpotato whitefly adults were observed on squash than on tomato, eggplant or okra. In a preliminary trial in a commercial tomato field, squash was planted in 100 ft long sections of 3 rows and alternated with 100 ft sections of 3 rows transplanted about 2 weeks later with tomato. More sweetpotato whitefly adults were observed on squash than on tomato but no impact on the number of adults on tomato adjacent to the squash was observed relative to tomato adjacent to the tomato. In the fall of 1993, squash was planted on one half the length of either three or six rows on one side of four commercial tomato fields. The other half of the length of each field and the remaining rows of each field were transplanted with tomatoes. The tomatoes adjacent to squash and the tomatoes adjacent to tomatoes were sampled weekly for adult sweetpotato whitefly using the beat pan method and for incidence of tomato mottle geminivirus symptoms. The results indicated that six row plantings of squash resulted in fewer sweetpotato whitefly adults on adjacent tomato and also resulted in a delay in virus incidence. The three row plantings of squash had no effect on either the number of sweetpotato whitefly adults or virus incidence.

TABLE F. Summary of Research Progress for Section F - Integrating Techniques, Approaches and Philosophies in Relation to Years 1 and 2 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
F.1 Risk Assessment.	Yr. 2: Interface with objectives for spatial analysis, network activity, ecosystem models and design risk assessment procedures for whitefly.		X	SPW population survey results are being incorporated into GIS systems. Work to determine the most efficient sampling method is progressing well. GIS systems for predicting virus spread have been used for tomato growers in northern Mexico. Still, no national evaluation panel to characterize risk assessment needs and procedures has been formed.
F.2 Spatial Analysis and GIS.	Yr. 2: Establish a network of user-information coupling participants. Input of spatial data. Look at other pest problems.		X	Crop sequencing and spatial arrangement studies are continuing on an area-wide basis in AZ, CA, and TX and much of this data is being displayed on GIS systems. The need for an area wide approach to SPW management is now generally accepted. Still, no national center to coordinate a national network of spacial analysis with GIS capabilities has been established.
F.3 Ecosystem modeling.	Yr. 2: Develop site-specific models in all participating states. Define appropriate resolution of modeling activity. Address other pest problems.		X	Survey data from CA, TX, and FL are continuing to be used for the development of simple models for SPW growth and movement. Work in the HERMES environment to model interactions between SPW and two of its natural enemies had begun. No National ecosystem model panel has been established, as of yet.
F.4 Networks.	Yr. 2: Teleconferences on SPW nationally. Expand to agricultural ecosystem management. Coordinate GIS with networks.		X	The NBCI bulletin board in on line and accessible through Internet. This BBS has a SPW forum and is available for the dissemination of information and for communication. The Silverleaf Whitefly Management Committee has also installed a BBS.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
F.5 Integrated Extension Programs.	Yr. 2: Develop procedures for data capture at local sites throughout the country and expand to other significant pests. Access spatial data and ecosystems models. Incorporate programs with existing IPM programs.		X	Task-forces/committees devoted to the collection and dissemination of information on whitefly management have been established in several states. An extensive training program for extension personnel and growers is being developed and the information network is expanding. These activities will facilitate the rapid transfer of research information to extension personnel and producers.

RESEARCH SUMMARY

Section F: Integrated Techniques, Approaches and Philosophies

Compiled by
Jose M. Amador, Donald A. Nordlund and Dennis D. Kopp

The sweetpotato whitefly is a complex problem and the solution to that problem will also be complex. Our efforts to find solutions involve research on taxonomy, virus vectoring ability, behavior, susceptibility and resistance to conventional pesticides, biological control agents, ecology (both local and regional), agronomic practices, host plant resistance, and etc. This research activity involves both traditional and cutting edge scientific techniques. As individual scientists we tend to become increasingly specialized in our activities and to interact with others specializing in similar research areas. However, the development of complex solutions to complex problems, such as the whitefly, will require the integration of the masses of data that we are all collecting into specific integrated pest management processes. That is what this whole meeting is really about - how do we network with each other so that our research results are integrated into pest management strategies for whiteflies in all of the different cropping systems that we have. This meeting provides the forum for a great deal of networking and cooperation.

Section F, Integrated Techniques, Approaches, and Philosophies is an interesting section, since it should really consist of all of the meeting participants, not just a few modelers and computer people. There are abstracts throughout this publication that could easily be placed in this section, so this summary will draw on all of the reported progress.

F.1. Risk Assessment

During the last year we have made considerable progress regarding the taxonomy of the insect, and this will considerably improve our ability to assess risk. We have also become more aware of the variety of risks that are associated with the whitefly (yield loss due to damage, virus transmission, reduced crop value due to honeydew contamination, and increased production costs due to control expenditures. Risk assessment must also take into account economic and social risks relating to impacts on agricultural support industries, rural communities, and rural populations. Also, models, using GIS systems have been developed to track population development, both historically and in real time. These models are improving the decision making process related to management options.

F.2. Spatial Analysis and GIS

GIS/geostatistics technology is being utilized in Arizona, California, Florida, and Texas to gather information on whitefly population dynamics, cropping systems, and risk.

F.3. Ecosystem Modeling

Population monitoring of whiteflies, associated viruses, and natural enemies is being conducted across the southern states. Much of this work is being interfaced with GIS/geostatistics technology. A Hierarchical Environment for Research Modeling of Ecological Systems is being used to model the interactions of whiteflies, their distribution, population dynamics and natural enemies.

F.4. Networks

The NBCI bulletin board is on-line with a SPW forum, which can be used by administrators, scientists, and growers to access information on whiteflies and to communicate with others. A telephone hotline and

Computer Bulletin Board have also been established by the Silverleaf Whitefly Management Committee in California.

F.5. Integrated Extension Programs

A multi-state task-force has been established for the development and dissemination of management information related to whiteflies. The goal is to provide educational resources in various formats for use by extension educators, field representatives, and growers. This multi-state task force includes scientists from Florida, Georgia, Texas, Arizona, and California. Educational materials will be available by 1995 in manual, slide-tape, video, and computer formats.

Overview and Recommendations

A. Ecology, Population Dynamics, and Dispersal

Considerable progress has been made in the area of population ecology, migration and dispersal, sampling, economic thresholds, and modeling of population dynamics. The seasonal cycle of *Bemisia tabaci* Strain B has been extensively documented and described in all regions where whitefly is a significant pest, including the recent incursion of whitefly into the southern portion of the San Joaquin Valley of California. Host preference, host-related fitness, and some of the factors influencing host selection, immature development, and oviposition have also been described.

The spatial distribution of whiteflies has been well documented and significant progress has been made in the development of efficient sampling methods and plans for all life-stages in cotton and melons. Additionally, relationships between various adult sampling methods and immature densities have been established. In relation to sampling for pest management application, binomial sampling methods for classifying adult populations for decision-making have been devised for cotton and melons based on whole leaf counts. Considerable progress has been made in defining the relationship between densities of whiteflies and crop quality and yield for cotton, melon, lettuce and kai choy.

Computer modeling efforts to quantitatively describe and predict population dynamics has progressed favorably. The influences of natural enemies and cultural control aspects are being emphasized in site-specific models for several crops. Ecosystem level efforts are emphasizing reproduction and movement on a regional cropping scale.

Good progress has been made in understanding many of the biological and ecological factors influencing dispersal by adult whiteflies, including physiological condition, behavior, sex and host plant physiology. These studies are beginning to define when whiteflies will move and what the consequences of this movement will be. Mark-recapture studies have characterized patterns of migration and dispersal on a scale of several kilometers. Combined with modeling efforts, results could enhance our understanding of how to manipulate crop sequences and patterns to suppress whitefly populations.

<u>Recommendations</u>

1. Work should continue on characterizing seasonal host associations of whitefly in the San Joaquin Valley, particularly in regards to northward movement and establishment.

2. There is a clear need to establish standardized sampling methods, particularly within a given crop. The lack of standard methods prevents direct comparisons of management techniques and population ecology studies between investigators in different areas of the country.

3. Although action/economic thresholds are available for two major whitefly hosts, much more effort is needed to establish similar thresholds for many more field and greenhouse crops. Development of thresholds should consider the different efficacies associated with chemically- and biologically-based control measures.

4. More research is needed to describe virus/whitefly/plant interactions and to establish action/economic thresholds for whitefly-transmitted viral diseases and feeding disorders.

5. Effort is needed to begin linking seasonal patterns of whitefly infestation with migration and dispersal between crop and noncrop hosts on a regional scale.

B. Fundamental Research, Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Vector Interactions

The 1994 action plan review/discussion of the B Section goals focused on several relevant aspects: (1) a discussion of the biotype/species question, biological, genetic, evolutionary, and phylogenetic considerations, and the proposed species nomenclature for the 'B' biotype as *B. argentifolii*, (2) the increased importance of whitefly-transmitted viruses in vegetable and fiber crops, (3) the sticky cotton problem and biochemistry of the honeydew, (4) morphological and anatomical characteristics of the adult whitefly mouthparts and associated organs involved in virus transmission, and (5) toxigenic effects of feeding by immature stages and induction of host plant proteins.

Research goals outlined in 1993 for the eleven subject areas in the B subsection were either met or partially addressed in all cases. Excellent progress has been made in the biological and genetic characterization of the biotype/species complex issue, and the complexity of the situation with respect to apparent diversity of *B. tabaci*, worldwide, is now apparent. A new species name, *B. argentifolii*, has been proposed to replace the prior designation, the 'B' biotype, which has been applied since the discovery of this new pest in 1988-89. However, it is also clear that the complexity of the situation new requires a detailed examination of biological and genetic characteristics relative to host plant colonization, intermating potential, virus transmission capabilities, and insecticide resistance of *B. tabaci* populations worldwide, in order to more fully understand the dynamics of whitefly-host-virus interactions that are of critical importance to implement effective integrated management strategies.

A substantial effort is needed to investigate the distribution and identification of whitefly-transmitted viruses, with an emphasis on uncharacterized geminiviruses and etiology. Efforts must be devoted to defining the basis of whitefly vector-virus relationships and the underlying mechanism of specificity. Cultivars with resistance to whitefly-transmitted plant viruses must be developed using traditional breeding and engineered strategies in a combinatorial manner. Criteria for identifying the prototype viruses that should be targeted in such resistance programs must be evaluated and defined.

Additional research is needed to elucidate the biochemical and physiological factors that govern host plant-whitefly interactions, and to determine the basis of phytotoxic-like host plant responses to whitefly feeding. Biochemical studies are needed to better understand the putative role of microbial endosymbionts in whitefly ecology, and with respect to the processing of phloem sap upon which whiteflies feed. There is also a need to better understand whitefly behavior with respect to insect-host plant interactions that affect the suitability of plants as reproductive or primarily feeding hosts for whitefly adults. The characteristics of the plant that discourage, attract, or permit whitefly colonization need to be more thoroughly investigated in order to identify relevant host plant factors which could be modified through plant breeding or genetic engineering approaches to develop cultivars with whitefly resistance.

C. Chemical Control, Biorationals, and Pesticide Application Technology

Significant progress was made in achieving the research goals in year 2. Cooperative efforts to further evaluate insecticides and biorationals for SPW control on cotton and vegetable crops proved to be very successful. Data generated from these research efforts led to the Special Local Needs registration of several effective insecticides for the control of SLW. Efforts to develop effective ground and aerial application technology were continued and are expected to provide improved spray deposition in the future. Significant progress was made in the development of economic thresholds on several crops. A standardized technique to monitor insecticide resistance has been developed, and plans are being made to implement it regionally. Although preliminary efforts have been made to examine the genetics of resistance and effects on insecticides on natural enemies, analysis shows the need for expanded efforts.

Recommendations

1. Continue insecticide evaluations on non-pyrethroid combinations, biorational combinations and other alternative modes of action.

2. Further examine full-season insecticide rotation studies utilizing combinations of conventional insecticides and biorationals.

3. Expand economic threshold research and resistance monitoring on a regional basis.

4. Increase research efforts to compare spray deposition between aerial and ground applications.

5. Increase research efforts of impacts of chemical control on natural enemies.

D. Biocontrol

Making progress on a many of the goals listed under Section D depended on completing surveys of indigenous natural enemies and making significant progress on those detailed under D8 (Systematics). With the support of all agencies involved in the National Research and Action Plan, we now have the support, methods and personnel to move into years 3-5. At the meeting in Orlando, FL there was as consensus of opinion that:

Recommendations

1. We should have an increased and coordinated effort to evaluate the many natural enemies available in culture. The lack of coordination and funding was identified as a major weakness in the biological control effort.

2. It was suggested we convene a separate meeting similar to that held for the chemical control section (Section C) in Austin TX. This meeting would include specific project development.

3. These projects (2 above) should be funded by APHIS.

4. The funding would have to be at a level that would support the evaluation needed of the many organisms currently in culture. This funding would have to be greater than $10,000 per cooperator.

5. Because of the large number of natural enemies available and not being evaluated, there were questions about the need to continue foreign exploration at this time.

E. Crop Management Systems and Host Plant Resistance

Extensive effort is being expended to identify whitefly resistant germplasm in broccoli, cauliflower, collard, kale, peanut, melon, lettuce, tomato and cotton.

Trap crops as potential control approaches, and water management and use of plant growth regulators are being investigated as potential methods of modifying plant growth and development to avoid, or in some other way, offset optimum conditions for whitefly population increase.

Recommendations:

1. Initiate studies to characterize mechanisms of host resistance to whiteflies in major crop species.

2. Develop cultural and crop management methods as non-chemical components of whitefly IPM systems.

F. Integrated Techniques, Approaches, and Philosophies

Within the framework of the 5-year plan, efforts to integrate risk assessment information, spatial analysis and GIS, networking, ecological modeling, and extension programs have progressed, but slower than anticipated. There are tremendous opportunities for integration of techniques and approaches in the management of whiteflies. It is our hope, that as we develop more information on whiteflies, the integration of that information into IPM programs will increase.

Recommendations:

1. We have asked that Dennis Kopp serve as co-chair of this section, replacing Jose Amador.

2. Cooperate with Dr. Peter Ellsworth in his coordination of the development of a whitefly slide set for all Cooperative Extension Service Programs in states affected by whitefly.

3. Under Risk Assessment, work will continue on the goals for years 1 and 2. Risk should include both an economic and a social risk component. Merrit Nelson will continue as champion for this research approach.

4. Under Spatial Analysis and GIS, work will continue on the goals for years 1 and 2. Dean Haynes will continue as champion for this research approach.

5. Under Ecosystem modeling, work will continue on the development of site specific models in all participating states. Jon Allen will continue as champion for this research approach.

6. Under Networks, work on expanding the use of the network for distribution of information on agricultural ecosystem management and GIS data. Bob Flanders will continue as champion for this research approach.

7. Under Integrated Extension Programs, work will continue on whitefly capture data collection at local sites throughout the country. The training material on management resources to aid producers in areas affected by whiteflies will be developed and distributed. John Norman will become champion for this research approach.

APPENDIX A

MINUTES OF THE SWEETPOTATO WHITEFLY (SPW) TECHNICAL WORKING GROUP MEETING

SECOND ANNUAL REVIEW OF SPW FIVE-YEAR NATIONAL RESEARCH AND ACTION PLAN
HELD IN ORLANDO, FLORIDA
JANUARY 24-27, 1994

JANUARY 27, 1994, 11:30 AM

Dr. Robert M. Faust called the SPW Technical Working Group to order, requesting from Marilyn Reega the registration count (183) and number of foreign meeting attendees (19), representing Mexico, Guatemala, Venezuela, Peru, Dominican Republic, Israel, and France.

Finalization of Progress Report:

Dr. Henneberry and Marilyn Reega reported that they had been advised that at least two additional research progress reports would be sent for inclusion in the final ARS publication of the proceedings of this meeting.

Dr. Henneberry advised the Co-Chairs of the six sections that the overview and recommendations for each section, and completion of 2nd year table entries are to be sent to the ARS laboratory in Phoenix no later than 2/14/94. Marilyn asked that this input be provided to her either by electronic mail or computer disk. Dr. Faust requested that the summaries include technology transfer accomplishments in 1993 which have impacted the agricultural community as a whole (growers, commodity groups, state departments of agriculture, universities, seed producers, etc.) He reminded attendees that over the next 3 years of the plan, producers will be expecting additional technologies to converge on the SPW problem. A discussion between Drs. Kopp, Toscano, Godfrey, Carruthers, Natwick and others followed regarding such accomplishments in the San Joaquin and Imperial Valleys, as well as Rio Grande Valley, and areas in Florida. Dr. Faust asked that Co-Chairs make a critical analysis of their group's progress in relation to the original 5-year plan initiatives, and to assess wherein their strengths and weaknesses lie. A discussion followed that indicated some weaknesses were noted overall, especially in terms of scientific effort for evaluation of natural enemies at the field level, a need for increased taxonomic input, and a need for increased interagency coordination. It was determined that these issues should be discussed by the USDA SPW Research, Education and Implementation Coordinating Group in a meeting to be held in the near future.

Dr. Faust advised that the ARS publication should be completed within two months after receipt by his office (April-May). Mrs. Deanna Guy and Marilyn Reega are to coordinate this activity and will provide Dr. Faust with a current mailing list of meeting participants. Dr. Faust raised the issue of the title for the publication in view of the acceptance by ESA of a new species with the common name of silverleaf whitefly (formerly sweetpotato whitefly, Biotype B). Tom Bellows and Tom Perring addressed current nomenclatural issues surrounding the SPW. Should we:

a. leave *B. tabaci* as is until ESA officially publishes the new identification;
b. use both *B. tabaci* and *B. argentifolii* in the 1994 supplement to the plan;
c. note 'A' and 'B' strains along with *tabaci/argentifolii*;
d. Make no changes to the 1994 supplement to the plan until next year

Since no consensus could be reached, Dr. Faust decided that the USDA Coordinating Group will discuss and determine this issue. For the cover of the 1994 progress report supplement, Dr. Faust will recommend that silverleaf whitefly (formerly sweetpotato whitefly) be used.

For the 1994 research year (1995 annual review), the following Co-Chairs were named to the six research and implementation area sections:

Section A:	Marshall Johnson and Larry Godfrey
Section B:	Jeff Shapiro and Judy Brown
Section C:	John Palumbo and Phil Stansly
Section D:	Oscar Minkenberg and Kevin Heinz
Section E:	Eric Natwick and Alvin Simmons
Section F:	Dennis Kopp and Don Nordlund

Planning for the 1995 Annual Progress Review Workshop:

Tentative Dates: January 28-30, 1995: Saturday, January 28 (travel/registration day), Sunday, January 29, and Monday, January 30.

Tentative Location: San Antonio, TX

Local and State Coordinators: Ray Carruthers and David Riley

Annual Review Program Chairs: T. J. Henneberry and N. C. Toscano

It was also determined that the January 1996 meeting would be held in San Diego, California.

The merits of inviting industry to the next annual review meeting were discussed. Dr. Akey stated that specific invitations to industry for participation in SPW review meeting events be made in the last half of October and in November by someone familiar with the industrial technical representatives. The format for presentations by industry would need to be coordinated with the local arrangements committee. Dr. Akey noted that since frequent changes occur in industrial responsibilities and regional representation, merely mailing meeting announcements to past industrial participants is not sufficient. Dr. Toscano stated that he would do this for the 1995 meeting and requested Dr. Akey to assist him. Dr. Toscano believes that industry participation should be confined to discussions limited to only those products which have proven effectiveness against the whitefly.

The consensus was that posters were a positive addition to the meeting, but they should have more time for display. This, of course, is a matter of costs - based on numbers of participants, which determines the cost of leasing poster boards, rooms and hotel space available for poster displays.

Meeting Format: Dr. Mayer stated that he felt the general meeting scheme for this year's workshop was well formatted. Others suggested that more informal "breakout" discussions should be planned. Dr. Henneberry urged the Co-chairs to plan in advance for such "focus group" meetings, keeping in mind that availability of hotel space may be limited, requiring small groups to meet in the lobby areas or elsewhere in order to accomplish their objectives. In any event, meeting planners (those making hotel arrangements, etc.,) **MUST** be kept advised of these needs as far in advance of the actual meeting as is possible.

Co-Chairs were requested to identify key speakers and/or issues and to limit the number of speakers in the section in order to better utilize the time allotted for the section to hold discussion and planning sessions.

Interim Progress Reports: Dr. Coppedge advised that he planned to continue requesting input for interim (biannual) research progress reports to be provided to researchers, growers and the agricultural community in general, utilizing the APHIS network. This information could also be disseminated to various electronic bulletin boards.

SPW Technical Working Group Meetings: Dr. Faust advised that the SPW Technical Working Group meetings are open to anyone interested in participating.

New Priorities and Funding Considerations: Dr. Coppedge advised that until Congress approves the 1994 budget, monies were not available with which to provide additional funding needs. He noted that the IPM Working Group which determines the 10 most serious pest problems has not put the SPW on the list because it has not been demonstrated that usable areawide management approaches to control this pest are yet ready. Therefore, he requests input be provided him on those components and areas of research which are developed and hold promise as elements of areawide IPM for the SPW as they come on-line.

Dr. Coppedge requested that the various State representatives need to update their individual research plans and funding needs for FY1994, prioritizing their most urgent needs, and providing him their input as soon as possible (2-3-pages should be adequate).

Dr. Robert Riley requested that the draft progress report be mailed to all participants in ADVANCE of the meeting in order for participants to be able to have a complete "picture" of all areas of research progress, and therefore, determine ways in which collaboration across section/disciplinary lines might be accomplished. Cost of reproduction of this draft document is approximately $5 per packet, plus mailing costs of $2.50 or more each. For 200 participants, this becomes a costly matter. Although the SPW Registration Committee has been able to provide several thousand dollars from the previous year's fees to the next year's Committee, these funds must be preserved for the eventuality of unexpected hotel costs incurred at succeeding meetings. USDA-ARS covered $1042 miscellaneous of the current meeting costs directly out of laboratory operating funds in order to assure that the actual meeting costs would be paid in full. At least half of the funds generated by the registration fees were collected at the meeting site (not in advance of the meeting).

Issues for USDA SPW Research, Education and Implementation Coordinating Group: This group is comprised of representatives from all involved agencies: ARS, APHIS, CSRS, CES, and the SAES; R. M. Faust and J. R. Coppedge from ARS; Robert Riley, CSRS; Harold Browning from SAES; N. C. Leppla and D. E. Meyerdirk from APHIS; and Dennis Kopp from CES. Dr. Faust further advised that this interagency coordinating group was the source for forwarding all serious issues to upper administrative levels for consideration.

International issues: Dr. Mayer discussed an upcoming BARD-Sponsored International Workshop on *Bemisia tabaci*, which will be held in Israel October 2-7, 1994 at the Shoresh Hotel. Interested parties should advise Dr. Mayer or Dr. Dan Gerling of their intention to attend the meeting ASAP. Space is limited - participants will be selected on a first-come, first-serve basis. This meeting should provide a good forum in which to build cooperation/collaboration of SPW issues with other countries worldwide.

The question of whether there should be participation of representatives from foreign countries in the SPW 5-year annual progress review workshops was raised and discussed. It was noted that a number of countries with this pest problem have established their own SPW working groups, are having similar meetings and workshops, and likely, for the most part, would be interested in listening and learning from our meeting, but not as active participants. It was suggested that a very short (2-minutes or so) period of time be allotted for each foreign visitor to make comments or suggestions as a part of the program.

Other Items from Floor:

Dr. Faust submitted for the record suggestions for a reorganization of the action plan and change in the workshop format developed by Dr. Phil Stansly, University of Florida. Time did not allow discussion of the submittal, but it is included for comment in these minutes by the SPW Technical Working Group:

I suggest we consider bringing together the present 6 sections into 2 sections:

(1) Bionomics of Whiteflies and Associated Viruses (formerly Sections A and B)

(2) Management of Whiteflies and Associated Viruses (formerly Sections C, D, E, and F).

The current six sections would become subsections of these two main focus areas of the progress review workshop. The 5-year research and action plan would likewise be combined into two sections without necessarily changing any of the individual items.

There would be 2 days of meetings; the first devoted to 2 plenary sessions; Section 1 would report in the AM and Section 2, in the PM. Each session would consist of 20-minute presentations on representative subjects from each of the sub-sections. The second day would consist of 2 concurrent break-out sessions, one for each section.

This format should provide a good balance between formal and informal discussions, general progress updates and worker-to-worker interaction. Comments are invited and should be forwarded to Tom Henneberry, ARS, Phoenix, AZ.

Dr. Judy Brown expressed her concern that the SRIEG working group was set up for the Southeastern region of the U.S., and although the Western contingency were welcomed to their meeting, she felt that the Western/Southwestern researchers involved in virus/vector issues needed their own group (WRCC-87). In addition, some discussion indicated that other agencies such as SCS, EPA, etc. should be included in, or at least kept aware of, the issues and accomplishments reached toward meeting the goals of the SPW 5-year research and action plan. Dr. Henneberry advised that because of delayed air traffic, the WRCC-87 meeting originally planned to convene during the Orlando meeting had to be cancelled. Dr. Henneberry will keep the WRCC-87 members aware of upcoming meetings. Further discussion indicated the need to involve more scientists in the plant physiology and other discipline areas to provide coordinated efforts in plant virus/vector research.

Interest was noted in continuing to hold regional and special research area meetings in conjunction with the SPW annual progress review workshops. Such meetings, space requirements, times, etc., should be coordinated with the SPW annual review program chairs and the local and State coordinators well in advance of the meetings.

Dr. Faust adjourned the SPW Technical Working Group Meeting at 1:30 PM.

Respectfully Submitted,

Marilyn T. Reega, Secretary
USDA-ARS-Western Cotton Research Lab
Phoenix, AZ 85040

ATTENDEES OF SPW TECHNICAL WORKING GROUP MEETING

Robert M. Faust, Presiding

January 27, 1994
Orlando, FL

NAME OF ATTENDEE PHONE	AFFILIATION/ADDRESS
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Judith Brown (602) 621-1402	Plant Sciences, Univ. AZ
Ray Carruthers (210) 969-4852	USDA-ARS, Weslaco, TX
James R. Coppedge (301) 504-5541	USDA-ARS-NPS, Beltsville, MD
Robert M. Faust (301) 504-6918	USDA-ARS-NPS, Beltsville, MD
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Dean Haynes (505) 521-1487	New Mexico State Univ.
Kevin Heinz (916) 752-4784	Univ. CA, Davis
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Oscar Minkenberg (602) 321-7714	Univ. AZ, Tucson
Steve Naranjo (602) 379-3524	USDA-ARS-WCRL, Phoenix, AZ
Eric Natwick (619) 352-9474	Univ. CA Coop. Ext., El Centro, CA
Don Nordlund (210) 969-4866	USDA-ARS-BCPRL, Weslaco, TX
Lance S. Osborne (407) 884-2034	Univ. FL, Apopka, FL
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Robert Riley (202) 401-4781	USDA-CSRS, Rm. 330 Aerospace Bldg., Washington, DC 20250
Nick Toscano (909) 787-5826	Dept. of Ent., Univ. CA, Riverside

AGENDA
SPW TECHNICAL WORKING GROUP MEETING
Orlando, FL
11:30 AM - 1:30 PM, January 27, 1994
R. M. Faust Presiding

- INTRODUCTORY REMARKS
- REPORT OF MEETING ATTENDANCE, ETC.
- FINAL REPORT/ASSIGNMENTS/DEADLINES
  - -- Foreword, technical summary, goals and objectives, status of SPW problem, progress reports and work plans, overview and recommendations, appendices
  - -- Minutes of SPW Technical Committee meeting
- 1995 PROGRESS REVIEW WORKSHOP
  - -- Organizers and program coordinators, local and state coordinators, section leaders/co-chairs, etc.
  - -- Date and location
  - -- Format/evaluation criteria/recommendations
- INTERIM PROGRESS REPORTS
- SPW TECHNICAL WORKING GROUP MEMBERSHIP/MEETING PARTICIPANTS
- NEW PRIORITIES AND FUNDING CONSIDERATIONS
- ISSUES FOR SPW INTERAGENCY COORDINATING GROUP
- INTERNATIONAL ACTIVITIES
- OTHER ITEMS FROM FLOOR

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APPENDIX B

MEETING AGENDA

SECOND ANNUAL PROGRESS REVIEW OF THE 5-YEAR NATIONAL RESEARCH AND ACTION PLAN FOR DEVELOPMENT OF MANAGEMENT AND CONTROL METHODOLOGY FOR SWEETPOTATO WHITEFLY, Bemisia tabaci Gennadius

Program Coordinators:

T. J. Henneberry *USDA-ARS, Phoenix, AZ*

and

N. C. Toscano *Univ. of CA, Riverside*

Local and State Coordinators:

R. T. Mayer *USDA, Orlando, FL,*

H. W. Browning *Univ. of FL, Lake Alfred*

P. A. Stansly *Univ. of FL, Immokalee*

January 24-27, 1994

Radisson Plaza Hotel, Orlando, FL

MONDAY, JANUARY 24, TRAVEL DAY

1:00 - 6:00 PM	Registration - 2nd Floor Foyer
5:00 - 6:00 PM	WRCC-87 Meeting - Concord Room -- Biology and management of sweetpotato whitefly, *Bemisia tabaci*
6:00 - 7:00 PM	SPW Planning Committee Meeting - Concord Room, R. M. Faust and J. R. Coppedge, presiding
6:00 - 8:00 PM	Mixer, Ballroom - Level 2

TUESDAY JANUARY 25

7:00 - 8:00 AM	Registration and Continental Breakfast - 2nd Floor Foyer

Sweetpotato Whitefly Outlook
Program Announcements: T. J. Henneberry and N. C. Toscano
Ivanhoe Ballroom

8:00 - 8:15 AM	Workshop Introduction: J. R. Coppedge Workshop Goals and Objectives: R. M. Faust

Sweetpotato Whitefly Perspectives

8:15 - 8:30 AM	Connie Riherd, Assistant Director, Florida Department of Agriculture and Consumer Services
8:30 - 8:45 AM	Charles Matthews, Jr., Assistant Director, Florida Fruit and Vegetable Association - **CANCELLED**

Research and Action Plan Progress

Section A: Ecology, Population Dynamics and Dispersal
Co-Chairs: S. Naranjo, ARS, and M. Johnson, Univ. of HI

8:45 - 9:00 AM	Seasonal dynamics of sweetpotato whitefly and natural enemy populations on cultivated crop and weed hosts L. Godfrey, Univ. of CA, Davis
9:00 - 9:30 AM	Progress in development of sampling methodology, action and economic thresholds in cotton S. Naranjo, USDA-ARS, Phoenix, AZ P. Ellsworth, Univ. of AZ, Tucson
9:30 - 10:00 AM	Progress in development of sampling methodology, action and economic thresholds in vegetable crops D. Riley, Texas A&M, College Station J. Palumbo, Univ. of AZ, Yuma
10:00 - 10:15 AM	Sweetpotato whitefly dispersal and factors affecting inter-and intracrop movement J. Blackmer, Univ. of AZ, Tucson
10:15 - 10:30 AM	Break - Foyer

Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases and Virus Vector Interactions

Co-Chairs: R. T. Mayer, ARS, J. K. Brown, Univ. of AZ

10:30 - 10:45 AM	Status of sweetpotato whitefly nomenclatural issues T. Perring, Univ. of CA, Riverside
10:45 - 11:00 AM	Biological analyses of sweetpotato whitefly biotypes J. K. Brown, Univ. of AZ, Tucson
11:00 - 11:15 AM	Genetic variability in whiteflies A. C. Bartlett, USDA-ARS, Phoenix, AZ
11:15 - 11:30 AM	Sweetpotato whitefly honeydew analysis and enzyme degradation D. Hendrix, USDA-ARS, Phoenix, AZ
11:30 - 11:45 AM	Progress in determining characteristics of toxigenic effects producing sweetpotato whitefly-induced plant physiological disorders J. Shapiro, USDA-ARS, Orlando, FL
11:45 - 12:00 PM	Sweetpotato whitefly virus-vector relationships: acquisition, transmission and virus characterization J. Duffus, USDA-ARS, Salinas, CA
12:00 - 1:00 PM	Lunch

Section C: Chemical Control, Biorationals and Pesticide Application Technology

Co-Chairs: N. Toscano, Univ. of CA and J. Palumbo, Univ. of AZ

1:00 - 1:30 PM	Regional status of chemical control of sweetpotato whitefly on cotton, vegetables and ornamentals D. Riley, Texas A&M, College Station J. Palumbo, Univ. of AZ, Yuma N. Toscano, Univ. of CA, Riverside
1:30 - 1:40 PM	Progress and potential for development of biorational insecticides for sweetpotato whitefly control P. Stansly, Univ. of FL, Immokalee R. Severson, USDA-ARS, Athens, GA
1:40 - 2:00 PM	Progress in development of improved application technology for more efficient sweetpotato whitefly control W. Coates, Univ. of AZ, Tucson F. Bouse, USDA-ARS, College Station, TX
2:00 - 2:40 PM	Regional status of sweetpotato whitefly insecticide resistance monitoring management and genetics G. Liebee, Univ. of FL, Sanford D. Wolfenbarger, USDA-ARS, Weslaco, TX, P. Ellsworth, Univ. of AZ, Tucson N. Prabhaker, Univ. of CA, Brawley
2:40 - 3:00 PM	Progress in development of insecticide rotational systems for effective sweetpotato whitefly control D. Akey, USDA-ARS, Phoenix, AZ C. C. Chu, USDA-ARS, Brawley, CA

3:00 - 3:15 PM Effect of insecticide applications on sweetpotato whitefly natural enemies
W. Jones, USDA-ARS, Weslaco, TX

3:15 - 3:30 PM Break - Foyer

Section D: Biocontrol
Co-Chairs: L. Osborne, Univ. of FL, and L. Wendel, APHIS

3:30 - 3:45 PM U. S. parasite fauna: a regional assessment
T. Bellows, Univ. of CA, Riverside

3:45 - 4:00 PM Potential of fungal pathogens for sweetpotato whitefly control
R. Carruthers, USDA-ARS, Weslaco, TX

4:00 - 4:30 PM Cooperative research and implementation project for biological control of the sweetpotato whitefly in the Lower Rio Grande Valley of Texas
R. Hennessey, USDA-APHIS, Mission, TX
S. Legaspi, USDA-ARS, Weslaco, TX
D. Riley, TAMU-Exp. Sta., Weslaco, TX

4:30 - 4:45 PM Status of taxonomic and nomenclature studies of sweetpotato whitefly natural enemies
M. Schauff, USDA-ARS, Washington, DC

4:45 - 5:00 PM Factors affecting natural enemy host finding, host selection and impact efficiency
K. Hoelmer, USDA-APHIS, Brawley, CA

5:00 - 5:15 PM Report on exploration, collection, colonization evaluation and rearing of exotic sweetpotato whitefly natural enemies
L. Lacey, USDA-ARS, Montpellier, France
A. Kirk, USDA-ARS, Montpellier, France

6:30 - 9:00 PM Buffet Dinner and Poster/Exhibit Session - Ball Room

7:30 - 9:30 PM *Nicotiana* Research Team Meeting - Concord Room

WEDNESDAY, JANUARY 26

7:00 - 8:00 AM Continental Breakfast - Foyer

Section E: Crop Management Systems and Host Plant Resistance
Co-Chairs: D. Hardee, ARS, and R. Carruthers, ARS

8:00 - 8:15 AM Effects of cotton plant water stress on infestations by the sweetpotato whitefly
H. Flint, USDA-ARS, Phoenix, AZ

8:15 - 8:30 AM The potential use of cultural practices in the management of sweetpotato whitefly populations
S. Castle, USDA-ARS, Brawley, CA

8:30 - 8:45 AM Plant growth regulator manipulation of crop growth, fruiting and crop maturation and relationships to sweetpotato whitefly population development
R. K. Yokomi, USDA-ARS, Orlando, FL

8:45 - 9:00 AM Report on progress in identifying sweetpotato whitefly resistant germplasm in agronomically acceptable cultivated crops
E. Natwick, Univ. of CA. Cooperative Ext., El Centro

Section F: Integrated Techniques, Approaches and Philosophies
Co-Chairs: J. Amador, Texas A&M, and D. Nordlund, USDA-ARS

9:00 - 9:15 AM	Geostatistical analysis of the regional distribution of viruses transmitted by the sweetpotato whitefly M. R. Nelson, Univ. of AZ, Tucson
9:15 - 9:30 AM	Area and regionwide sweetpotato whitefly geographic information systems (GIS) in integrated pest management programs D. Haynes, Michigan State Univ, E. Lansing
9:30 - 9:45 AM	Progress in development of sweetpotato whitefly population modeling systems interfaced with crop and intercrop plant growth and development J. C. Allen, Univ. of FL, Gainesville
9:45 - 10:00 AM	Status of National Biological Control Institute information system and methodology for efficient input and access R. Flanders, USDA-APHIS, NBC, Hyattsville, MD
10:00 - 10:15 AM	Break - Foyer
10:15 - 10:30 AM	Current status of sweetpotato whitefly Extension systems for public awareness, communication to grower and current information networks for grower information J. W. Norman, Texas A&M, Weslaco

Research Needs and Priorities

10:30 - 12:00 PM	Sections A and B: Highlights and Priority Setting
12:00 - 1:00 PM	Lunch
1:00 - 2:00 PM	Sections A and B, continued.
2:00 - 2:30 PM	Sections A and B: Discussion and Recommendations
2:30 - 5:00 PM	Sections C and D: Highlights and Priority Setting
5:00 - 5:30 PM	Sections C and D: Discussion and Recommendations

THURSDAY, JANUARY 27

7:00 - 8:00 AM	Continental Breakfast - Foyer

Research Needs and Priorities (Continued)

8:00 - 10:30 AM	Sections E and F: Highlights and Priority Setting
10:30 - 10:45 AM	Break - Foyer
10:45 - 11:15 AM	Sections E and F: Discussion and Recommendations
11:15 - 11:30 AM	Closing Remarks, T. J. Henneberry and N. C. Toscano, Adjourn
11:30 - 1:00 PM	SPW Technical Working Group Meeting - Concord Room, R. M. Faust, moderator

APPENDIX C

LIST OF REGISTERED MEETING PARTICIPANTS
Orlando, FL, January 24-27, 1994

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APPENDIX D

D. H. Akey **February 14, 1994, Page 1 of 7 Pages**

Revised protocols for ground application of chemical trials against the Sweetpotato Whitefly (SPWF) in the 1994 growing seasons, based on information derived from the January, 1994 SPWF Review workshop at Orlando, FL. [1] [2]

In 1992, the severity of Sweetpotato Whitefly (SPWF) damage to crops across the Southern US required immediate measures to be instituted to reduce the damage. For this action, protocols for ground applications were established in a cooperative effort by the SPWF Workshop for Applications of Chemicals Against SPWF at San Antonio, TX, January 23-24, 1992, to obtain uniform tests that would generate data useful for comparisons of SPWF chemical trials in the 1992 growing seasons on several crops at a number of locations. Some agents were compared nationwide; others were restricted to comparisons specific to locations because of various requirements or conditions. The 1992 protocols were used for the 1993 growing seasons also. Now in 1994, with two years of experience and hindsight, the protocols have been revised to use this knowledge.

Sampling units that must be reported are set in bold type. The latter are a minimum. Investigators are encouraged to report as much detail as possible regarding methods, materials, meteorological conditions during the test periods, and particularly, leaf area of leaves sampled and some indication of the homogeneity of the SPWF distribution. It may be necessary to record this information as appendices, but it is important to acquire the data. **Retain raw data and summaries in addition to analyzed data and reports for regulatory agencies; e.g., EPA.** Raw data and summaries are used by them for statistical analysis for making determinations about the efficacy and usefulness of the compounds tested for section 18's and other regulatory categories.

Again, the objectives of the protocols that follow are to insure enough uniformity between trials to make some valid comparisons and draw useful conclusions about compounds, crops, and application methodologies as regards SPWF. The following protocols include, but are not limited to, the crops listed below.

Cotton
Peanuts
Vegetables

Tomatoes
Eggplant
Melons/cucurbits

Cole crops
Leafy greens.

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1 Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply its approval to the exclusion of other products that may be suitable.
2 Protocols established by the SPWF workshop at San Antonio, TX, January 23-24, 1992; revised at SPW workshop at Houston, TX, February 1992, and March 12 and 23, 1992.

Each researcher will need to communicate with the company product manager and /or the technical representative to request the amount of material needed for tests. Researchers should check with the contact person to establish reasonable lead times for requests of materials to assure timely deliveries without "crisis" deadlines.

Protocol I: Standardized sampling counts of SPWF. It is preferable to take samples before and after application but at the least sample weekly. **Distinguish SPWF immatures and adults from banded-wing whitefly (BWWF) or other species in your area for accurate data collection. Other species sometimes occur during specific parts of a season.**

A. **For eggs and immatures, counts will be taken from undersides of leaves.**

1. Counting methods: the counting method chosen is the choice of the investigator. However, one **method must be used consistently during the whole season** to aid statistical analysis; e.g. early in the population increase, it may be easy to do whole leaf counts, but later it may be only practical to do 4 leaf-disk counts/leaf; nevertheless, still make leaf-disk counts early in the season along with the whole leaf counts. This way there will be one counting method to generate data for the entire season analysis; and at the discretion of the investigator, earlier season data may be analyzed by a more sensitive method; e.g., whole leaf counts.

    a. disks; most investigators are using a single disk from each leaf sampled. Usually, the disk is being taken from the base of the leaf and centered on the main vein. Disk sizes have varied; e.g., diam. 1.13" = 1 sq inch = 6.45 cm sq; diam. 1.0" = 0.78 sq inch = 5.03 cm sq. Other sampling schemes have used 2 disks - one from each leaf half, or four 10-mm diam. disks/leaf, one from each leaf quadrant; but taken near the base of the leaf (3.1416 sq cm).

    b. grids; superimposed over leaf and counts within grid(s) taken.

    c. whole, half, or partial leaf.

2. Eggs will be reported as **eggs/cm^2**, usually from a fully expanded top leaf.

3. Immatures will be reported as **large nymphs/cm^2**, usually from a fully expanded leaf that has the most large nymphs present; e.g., cotton, typically sampled from a leaf within leaves 1-7 as counted from the top, off the main stem. Based on statistical review of these protocols by a bio-statistician, leaf sampling for immatures should be based on selection of the leaf (leaves) with the most large immatures. This may bias the immature population counts toward the "high" side but will produce more consistent samples with a lower variance than arbitrary selection of a particular leaf as numbered from the top or bottom of the plant. It will also help determine efficacy in the "worst-case scenario". This observation by a bio-statistician is based on a review of data of 2 year's work at 3 sites by the author and 1 year's work by a colleague at yet another site.

    a. Same sampling and counting schemes as for eggs.

    b. **Large nymphs will include large 3rd's, small 4th's, and red-eye nymphs (pupae).**

4. Leaf packaging and storage: It is convenient to seal leaves from individual plots in "zip lock" type plastic bags and record the plot and date data, etc., right on the bag with a permanent marker.

The material should be kept very cool, but not frozen, from the time of collection in the field and throughout storage in the lab. Leaves should be examined as quickly as possible via a stereo-microscope. This is a time-consuming process--be ready! Bags of leaves need to be examined for mold often, in order to set priorities for counting order (we have been unsuccessful in attempting to count dried leaves. Has anyone tried preservation by alcohol or something similar? Also, fungicidal spray may be useful).

B. For adults: experience from several locations across the country has shown that it is difficult to measure treatment effects on adults in small plot trials. Separation of treatment means are usually not statistically significant. This is primarily due to the movement of adults in and out of the plots. Also, methods to determine adult numbers during a regime of treatments are not necessarily the same as methods relevant to determine action thresholds for beginning trials. If your resources are very limited, you may make a decision not to sample adults. Adult counting methods include: the "leaf-turn" count technique, sticky card traps, sticky pan, and vacuum sampling; only the first 2 methods will be discussed.

1. **Leaf-turn method: counts should be reported per whole leaf.** This makes comparisons between crops difficult but attempts to report this per unit area of leaf have been unsuccessful.

    a. **sample 24 or 48-hr post treatment.**

    b. sample in early morning if possible.

    c. be careful not to disturb whiteflies in crop while sampling.

    d. leaves to be sampled are left to discretion of investigator. In cotton, one scheme has been to take an average of the sum of 3 leaves, one leaf each from the bottom, middle, and top of canopy.

2. Yellow sticky cards: counts will be reported as **SPWF adults/cm^2.**

    a. 24-hr sample time in 48-hr window.

    b. Card oriented perpendicular to row in a vertical position with plant.

    c. Card positioned somewhere between middle to lower third of plant; for low plants such as lettuce and curcurbit vines, place cards as needed close to top of plants and use cards appropriately smaller in size if needed.

    d. Card counted on both sides, area counted to be same throughout season.

    e. Chose "own appropriate size" card and amount of area of the card to count.

    f. Source of yellow sticky cards (**both sides sticky**) and methods of preparation

(1) Olson Products
P.O. Box 1043
Medina, Ohio 44258
(216) 723-3210
(216) 723- fax

3" X 5"; Pack of 25 cards	$ 6.95
Case of 26 packs (total of 650 cards)	$155.95
6" X 12"; Pack of 10 cards	$ 29.00
Case of 5 packs (total of 125 cards)	$116.00
8" wire stakes to hold cards (can be secured to wood poles)	
Pack of 10 stakes	$ 3.50
Case of 10 packs (total of 100 stakes)	$ 27.90

(2) Order cards most appropriate in size to use "as is" or to cut to size needed. It may be possible to custom order cards cut to specific sizes.

(3) There are sources of cards that are preprinted with a grid but I am unaware of where to obtain such cards that are sticky on both sides.

(4) Bring a roll of plastic cling wrap to the field and cover cards with it. Always mark card orientation by a mark or notch and have method for identifying the plot, date, site, etc. The ID can be as simple as ink via a felt pen over the cling wrap (in an area not to be counted) or a tiny preprinted label.

(5) Cards with SPWF are easily kept in a freezer until counted.

(6) Grids for counting can be easily scored with a felt-tipped pen right over the cling-wrap, i.e., the wrap does not need to be removed.

Protocol II: Standardized sampling, replicates, and treatments.

A. **For eggs and immatures: minimum of 4 replicates (plots)/treatment, and 5 leaves/replicates (remember that a test with more replicates will give better statistical separation due in part to the increased degrees of freedom. freedom in the statistical analysis of the data.**

B. **Adults: minimum of 10 leaf-turn samples or 1 yellow sticky card/replicate (plot).** [Authors experience: neither leaf-turn nor yellow card samples have resulted in statistical separation of different treatments in plots less than an acre].

Protocol III: Ground Applications [3]

A. Experimental design:

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3 See separate protocols for aerial application, pp 105-125 in 1992 Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly, Houston TX 1992, ARS-107.

1. Type: this is left to the discretion of the investigators but considerations should at least be given to the pros and cons of various designs; e.g., a, b, and c below; latter is recommended by author.

    a. Random block design with tiers of replicates with treatment position within tiers chosen at random. This design embeds check plots throughout the design and tends to negate effects of non-study parameters, but allows possibility of treatments to influence check plots by changing the populations around them (this has been observed by the author).

    b. Latin square. This places treatments and check plots uniformly throughout the design and is strong in reducing non-study parameter effects; check replicates may also be influenced by surrounding treatment replicates as in a). It requires that treatment numbers equal replicate numbers. However, it has the same disadvantage as the random block design as check plots may become dependent variables.

    c. Random block or Latin square design (check plots embedded in the design) but with a separate check block of untreated plots. The check block should have dispersed sampling points equal in number to the number of replicates/treatment in the accompanying random block or Latin square design. This allows the treatments to be compared to both embedded checks and the check block samples. It also allows the investigator to determine something about the independence (or dependence) of the embedded checks.

2. Regardless of the test design chosen, the investigators must consider the benefits of isolation of plots (replicates) or blocks to reduce the influence of SPWF movement between them. For example, in the row crop cotton, lower variance in data was observed in plots isolated by 3-fallow-row corridors and 20-ft alleys than by 2-row-corridors and 3-ft alleys (authors data).

3. The plot size and number of rows have been left to the discretion of the researchers because of the great differences in crop phenologies, morphologies, and systems.

4. Action thresholds for initiation of applications are to be determined by the investigators but Must be reported. The purpose of the action threshold must be considered. Is it to protect plant growth itself, prevent stickiness, or stop viral or toxin transmission? Also the degree of SPWF infestations in nearby crops and around the trial field may determine the action threshold level chosen. Perhaps most importantly, even if the SPWF population is low, has it doubled within 7 - 10 days? The latter is almost a sure indication for action (author opinion).

B. Application methods:

1. List all parameters including:

    a. Crop information; e.g., size, stage, fruit, season.

    b. Nozzles & types/row.

    c. Application equipment and details.

    d. Tank pressure in PSI (and if possible delivery PSI).

    e. Weather - at time of application.

f. Calibration.

g. Use only one method of application.

2. **Applications are to be applied by motorized ground equipment, back pack sprayers are not to be used (even if operated by pressurized gas tanks or motorized).**

3. Determine particle deposition to report percent coverage, droplet size in μg, and total deposition in $\mu g/cm^2$. This must be done at least once in each trial, usually at the time of densest canopy or foliage. Dye applications followed by determination of area covered, leaf washes of single leaf side, use of water sensitive papers, and microscopic examination are useful techniques to obtain these data. [4]

4. Action thresholds for initiation of applications are to be determined by the investigators but must be reported. The purpose of the action threshold must be considered. Is it to protect plant growth itself, prevent stickiness, or stop viral or toxin transmission? Also the degree of SPWF infestations in nearby crops and around the trial field may determine the action threshold level chosen. Perhaps most importantly, even if the SPWF population is low, has it doubled within 7 - 10 days? The latter is almost a sure indication for action (author opinion).

C. Chemicals:

1. **Follow rates suggested by company representative and report each as ai/ac.**

2. pH and alkalinity of application (mix) water:

   a. sample water and have it tested before applications start, if the source changes, once during the season, or any time that there is cause to question if the water quality has changed significantly.

   b. Collecting of application water for pH and alkalinity testing: container and volume: collect 1 pt. (475 ml) of water in a water tight, thoroughly-rinsed plastic bottle. Let the water run for two minutes before collecting the sample. Fill the container to the very top leaving as little air space as possible so CO_2 in the air does not mix with the water's components and raise its alkalinity. Keep samples cool.

   c. If buffering is required for pH adjustment for pH sensitive agents then consult with company contacts for that agent.

3. **Each agent must be tested in the field at least once with one treatment (season long) without an adjuvant. If an adjuvant is used in a second treatment or in following seasons, then an additional treatment must be conducted with the adjuvant alone.**

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4 Contact Dr. I. (Buddy) Kirk, USDA, ARS, SPA, Aerial Application Res, College Station, TX for technical information).

4. Investigators are to individually test agents for inclusion in these tests with the exceptions of specific company requests that the agent be tested with a second agent. If so follow a procedure similar to 3) above.

D. Application frequency:

1. Ideally, 10 applications are desirable; may be crop dependant.

2. Applications should be made every 7 days if possible but no longer than 14 days should pass between applications (exception is imidacloprid applied as a systemic, then crop should be closely monitored to determine when to initiate foliar sprays).

3. The number of applications may require that a lower rate be used for each application. Do not go below an effective rate for any one application. If the total application amount for the season exceeds the maximum allowed, the treated crop must be destroyed after the end of the experiment as a research trial and must not exceed parameters (e.g. 10 ac in size) that would qualify it as needing an experimental use permit (EUP).

E. Crop Parameters:

1. Yield (in units used for each specific crop).

2. Phytotoxicity, if present; may require rate reduction on sensitive crops.

3. Alteration of plant phenology/morphology, or any other growth differences from the check.

APPENDIX E

ORGANIZATIONAL MEETING OF THE WHITEFLY RESISTANCE MANAGEMENT WORKING GROUP

Acting Co-Chairs: T. J. Dennehy and N. Prabhaker
Orlando, Florida, 26 January, 1994

Rationale

Information exchange is critical to promoting the goals of resistance management. Industry, research and extension personnel faced with challenges related to chemical control of the whitefly have an especially urgent need to enhance information exchange, especially on matters influencing pesticide efficacy. Recognizing this need, a whitefly resistance management working group has been established within the existing structure of the 5-Year National Research and Action Plan focusing on sweetpotato whitefly. The first formal meeting of this group will be in 1995.

Mission of Working Group

The principle mission of the group is to enhance information exchange between research and extension personnel involved in resistance management.

Focus will be given, but not limited to:

1. Resistance monitoring methodology

2. Insecticide efficacy trials and the correlation of laboratory and field estimated of chemical potency

3. Mechanisms of resistance, cross- and multiple-resistance phenomena

4. Resistance management strategies: devising "best-guess" recommendations for thwarting resistance to new, as well as established products

5. Identify and promote collaborative projects between states, universities and USDA agencies

6. Maintain national overview of whitefly resistance management systems

Group Membership and Governance

Individuals from all interested sectors will be encouraged to be members of the group. However, to minimize conflicts between business/economic and scientific imperatives and realities, a two-tier membership will be maintained. Since the principal mission of the group is to promote information exchange within the extension and research communities, this group will control matters related to agenda and governance. The second level of membership will comprise individuals who have economic interests involving pesticide products (hereafter 'Industry'). Input from this sector of the membership is highly valued and to be encouraged. However, if issues on the floor have substantial economic overtones for specific 'Industry' members, the group leaders may limit input from 'Industry' members.

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A Chair and Secretary will be elected by the group. The acting co-chairs will be T. J. Dennehy (University of Arizona) and N. Prabhaker (University of California).

<u>Extension/Research Members</u>

Gary Leibee	University of Florida
Dan Wolfenbarger	USDA, Weslaco, TX
Eric Natwick	University of California, Extension, El Centro, CA
Peter Ellsworth	University of Arizona, Tucson
James Coppedge	USDA-ARS, Beltsville, MD
John Palumbo	University of Arizona, Yuma
Julius Menn	Cooperator, USDA-ARS, Tucson, AZ
Nilima Prabhaker	University of California, Brawley
Lance Osborne	University of Florida, Apopka
Nick C. Toscano	University of California, Riverside
T. J. Henneberry	USDA-ARS-Phoenix, AZ

<u>Industry Members</u>

Walt Mullins	Miles
Phil Odom	Nor-Am
Jeff Pacheco	DuPont